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ABSTRACT

A project evaluated general and specific learning objectives for undergraduate science practicals in institutes of higher education in the Netherlands. Of 50 institutes offering education in the natural sciences that were surveyed, 36 returned 2 instruments that were used to determine the perceived importance of the learning objectives and a background questionnaire. Results for university education (UE) and higher vocational education (HVE) obtained in this research were compared with each other and with results of a study of the Open University of the Netherlands (OUN). It was determined that differences between HVE and UE were smaller than differences between the OUN and UE and those between OUN and HVE; differences between the OUN and UE were smaller than those between the OUN and HVE. HVE classified more specific objectives concerning execution of experiments as indispensable than did UE. HVE emphasized practical laboratory skills, data interpretation, and confirmation of existing theories. UE attached little importance to practical skills, but emphasized hypothesis or model formulation and design of experiments to test hypotheses. The OUN emphasized the ability to define and solve problems, derive hypotheses from theories, and adapt models to new experimental results and put much less emphasis on laboratory skills. (Appendixes include 28 references and 28 data tables/charts from this study and the OUN study.) (YLB)

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Learning objectives for practicals in institutes of higher education in the Netherlands: A descriptive study

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The Open university of the Netherlands is responsible for developing and offering open, higher education in which special attention is paid to innovations in educational technology.
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For more than a century practicals haven been an integral part of higher education in science. Although the effectivity and efficiency of practicals as a didactic tool are at least questionable, it is impossible to imagine an education in the Natural Sciences without them.
This research project attemps to build new foundations for the use of practicals, based on their educational, didactic possibilities.

Learning objectives for practicals in institutes of higher education in the Netherlands.

A descriptive study

OTIC Research report 21.2

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Contents

Summary

The research described in this report is part of a research project on the *perceived importance* of learning objectives and end-terms for practicals in undergraduate higher science education. This report focuses on higher education in the Netherlands (HE) which is comprised of university education (UE) and higher vocational education (HVE). The results for UE and HVE are compared with each other and with the results of the Open university of the Netherlands (OuN), already published in an earlier report.
We are interested in determining whether the perceived importance of the objectives and end-terms depends on the type of institute (traditional face-to-face education or open distance education) and/or the type of education offered (monodisciplinary vs inter-/ multidisciplinary).
An inventory of learning objectives and end-terms for undergraduate practicals in the natural sciences, as contained in the literature, was made at an earlier stage of this project. The resulting list, consisting of a small number of general learning objectives and end-terms and a large number of specifications thereof (*specific* learning objectives and end-terms), is the starting point of the instruments used in the present research.
The respondents work on the faculties and/or departments of Dutch universities and higher vocational schools offering education in the natural sciences.
The major conclusions from the research are:
- The differences between HVE and UE (expressed as Δ), with regard to the evaluation of the learning objectives and end-terms, are smaller than the differences between the OuN and UE and those between OuN and HVE: Δ (HVE/UE) < Δ (OuN/UE) and Δ (OuN/HVE). In turn, the differences between the OuN and UE are smaller than those between the OuN and HVE: Δ (OuN/UE) < Δ (OuN/HVE).
- HVE differs from UE mainly with regard to learning objectives concerning the actual execution of experiments. HVE classifies a larger number of this type of specific objectives as indispensable than UE.
- The identity of the type of institute clearly comes to the fore. HVE emphasizes practical laboratory skills, interpretation of data and the confirmation of existing theories. UE attaches little importance to practical skills, but emphasizes the formulation of hypotheses or models and the design of experiments to test hypotheses (academic skills). The OuN attaches great importance to the ability to define and solve problems, to derive hypotheses from theories and to adapt models to new experimental results, and puts much less emphasis on laboratory skills (even less than UE).
- All three types of institutes consider communicative skills important (especially in writing), although the general learning objective 'to clearly describe the experiment' scores low. This inconsistency will be explained.
- Comparing three UE science disciplines (biology, chemistry and physics) with each other, we note that the difference between biology and physics is the largest. Chemistry often occupies an intermediate position. This can be ascribed to the characteristics of the different science practicals.
- In comparing the results from the three disciplines with those of the OuN, the OuN is most similar to biology (although the difference is still considerable) and least similar to physics. This is not at all strange since the Environmental Science programme at the OuN comprises a great deal of biology and chemistry with significantly less physics.
- There is only a slight difference between the answers of respondents who coordinate practicals and those who do not.
- It is not possible to point out differences between respondents offering monodisciplinary education and those offering inter/multidisciplinary education because of the small number of respondents from the latter group.

1 The Open university and other institutions for higher education

This report is part of a research project into the evaluation of learning objectives and end-terms for undergraduate science practicals in institutes of higher education. An earlier report *'Practical objectives at the Open university of the Netherlands: a descriptive study'* deals with the evaluation of learning objectives and end-terms for science practicals at the Open university of the Netherlands (OuN). The research described in this report is similar in form and concerns the evaluation of (the same) learning objectives and end-terms by more 'traditional' institutes of higher (face-to-face) education in the Netherlands (HE), both university education (UE) and higher vocational education (HVE).
In some respects, these traditional institutes differ so much from the OuN that it is quite conceivable that some of the objectives and end-terms for practicals to which they strive differ from those pursued by the OuN. This assumption is not so much based on the fact that the OuN has limited possibilities for organizing practicals, but rather on the different nature of the OuN, its underlying philosophy (open education instead of face-to-face education) and the different type of educational programme it offers (inter-/multidisciplinary instead of monodisciplinary). These differences have led to a reconsideration of learning objectives and end-terms within the OuN, which might result in a different perceived importance of these goals and objectives with respect to the more traditional institutes.
With regard to *nature of the institutions*, it can be said that the OuN as well as the open universities in other countries distinguish themselves from the other types of institutes by the fact that they put special emphasis on a number of freedoms which they offer to students. In principle, their students are free to study where and when they want and to choose their own pace of study. As a consequence, the number of times that students should be required to come to a specific place at a specific time in a specific phase of their study, e.g. for practicals, should be kept to a minimum. This should necessitate these institutions to choose those learning objectives and end-terms that are really necessary for their programmes from all the possible learning objectives for a specific domain of study. This, in turn, implies that these institutions need reconsider the role and function of practicals in the undergraduate part of their educational programmes and give priority to a certain type of learning objectives (e.g. academic or cognitive skills) at the expense of other learning objectives (e.g. motor skills).
With regard to the *type of educational programme offered*, it can be said that the OuN (as well as some fairly new disciplines within HE) offers multi- or interdisciplinary programmes. A typical example of such an educational programme is the Environmental Science programme at the OuN, which seeks an integration of the natural and the social sciences. All these programmes aim at an integration or synthesis of disciplines by putting special emphasis on evaluative or synthetic behaviour and by focusing on the syntactic structure of the various disciplines. In monodisciplinary programmes, on the other hand, the emphasis will be on analytic behaviour and on the substantive structure of a specific discipline.

Together these differences yield a 2 x 3 matrix, of which the cells can be compared with each other:

	(open) distance education	*face-to-face HVE*	*face-to-face UE*
monodisciplinary	most open universities	most HVE science faculties	most UE science faculties
inter-/multi-disciplinary	OuN	some new HVE science faculties	some new UE science faculties

For a more detailed discussion of the didactics of different types of practicals and the motivation for the use of this didactic method, the reader may refer to two articles on this subject listed in the bibliography (Kirschner and Meester, 1988; Kirschner, 1989).

The present report is the second in a series of reports concerning the empirical part of the research project '*Practicals in Higher Science Education*'. The first report discusses the results of a research carried out with the staff of the product group Natural Sciences on the perceived importance of learning objectives and end-terms for practicals at the OuN. Paragraph 2.2 gives a synopsis of the results of this research.
This report discusses the results of a research into the appreciation of learning objectives for practicals in other institutions of HE in the Netherlands; in comparison with the OuN. A third report will consist of the results of research into learning objectives and end-terms for practicals in institutes of (open) higher education abroad.

1.1 *Higher education in the Netherlands: the legislation*

Higher education (the *combination* of university and higher vocational education) is a recent development in the Netherlands. The different institutional types each have or had their own learning objectives and end-terms. To illustrate, we will quote from the laws in which UE, HVE, the OuN and HE are defined.

The Vocational Education Act (VEA, 1985) states:
"Higher vocational education is a form of higher education which is oriented toward the theoretical and practical preparation for the practising of vocations for which training at an institute of higher vocational education is required or useful, and which thus contributes to the personal development of the students and their functioning in society. Higher vocational education concurs with the final level of the advanced types of secondary education".

The explanatory memorandum of the Act states:
"The part 'preparation for the practising of a vocation' of the definition concerns one of the most important characteristics of higher vocational education and constitutes as it were the identity of this type of education.
The 'orientation' of HVE towards the acquisition f knowledge, insights and skills required to solve concrete problems connected wi ı the fulfilment of certain functions constitutes, in addition to the above-mentioned characteristic, a second essential

characteristic of higher vocational education. HVE is oriented towards the preparation for the fulfilment of functions at a high level. These functions set high standards with regard to independence, creative thinking and acting and social skills (dealing with people, teamwork, multidisciplinary cooperation, managerial ability etc.); the educational programme must provide for this. In conclusion of this characterization it should be pointed out that higher vocational education derives its high quality especially from the fact that the students learn to apply scientific methods, including scientific research".

According to the University Education Act (UEA, 1985):

"University education is a form of higher education which consists in the preparation for independent scientific work and the fulfilment of functions in society for which a university education is required or useful, and which contributes to the understanding of the interrelatedness of the sciences".

Unfortunately, there is no explanatory memorandum of this act.

Article 3 of the Open university Act (OuA, 1984) states that:

"The Open university has, with respect to the provision of education for adults, the role of providing higher education primarily via the use of distance teaching media and such that students can make use of it without restrictions on entry or programme composition.

The term 'higher education' is used to indicate a type of education which:

a. is oriented towards the preparation for independent scientific work or the fulfilment of functions in society for which scientific work or the application of scientific insights is required or desirable,

b. also contributes to personal development and to a sense of social responsibility with regard to scientific work and the application of scientific insights,

c. links up with the final level of the advanced types of secondary education".

The explanatory memorandum of this Act states:

"By setting up the Open university the government also intends to stimulate the innovation of both regular full-time and part-time higher education, both in form and in content. The Open university is clearly a part of the government's striving towards coherent totality of differentiated educational and research possibilities at the level of higher education.

The Open university offers higher education. The Open university Act is the first and sofar only educational act to describe what is meant by 'higher education'. Neither the UEA nor the VEA defines this concept.

The following elements of the description attract the attention:

a. its dual nature: the term 'higher education' is not unequivocal. Higher education is oriented either towards the preparation for independent scientific work (an objective derived from university education), or towards the fulfilment of functions in society for which scientific work or the application of scientific insights and methods is required or desirable (orientation towards application as in higher vocational education),

b. additional objectives of higher education are to contribute to personal development and to arouse a sense of social responsibility with regard to scientific work and the application of scientific insights,

c. the abstract indication of the level of this type of education: higher education links up with the final level of the advanced types of secondary education.

Consequently, the Open university should offer both 'UE-oriented' and 'HVE-oriented' education. Moreover, the Open university has to play an important part in 'the field of the innovation of higher education'".

These three acts will be replaced by the Higher Education and Scientific Research Act (HESRA, 1989). In the definition of concepts this Act states (article 1.1) that:

"- higher education comprises university education and higher vocational education;

- university education is a form of education which is oriented towards the preparation for independent scientific work or the professional application of scientific knowledge;
- higher vocational education is a form of education which is oriented towards the transfer of theoretical knowledge and the development of skills in close connection with vocational practise."

The explanatory memorandum of this Act describes the characteristic features of university education and higher vocational education:

"The characteristic feature of university education is that this form of higher education is inextricably connected with places where scientific research is carried out. A close relationship between this type of education and scientific research is desirable".

"The characteristic feature of higher vocational education is that there is a strong interaction between this form of higher education and vocational practice. This interaction comprises more than merely turning out graduates for the benefit of a certain sector of society. Another aspect of this interaction is the influence of vocational practice on the content of education".

The fact that the two types of education have merged to form one single type of education, i.e. higher education, does not mean that they will have to give up their own identity, judging by the following quotation from the explanatory memorandum of the Act:

"In the period to come, higher vocational education will receive the benefits from the recent structural reforms. For the majority of the new large HVE institutes this period will be one of relative stabilization of institutional, organizational and financial relationships. HVE will have to develop its own identity further as to form and content, in order to demonstrate that it takes up an independent and equal position in relation to UE. This equality does not imply that HVE should seek to resemble UE as much as possible or the other way round; this would undermine the specific roles these two types of education have to play. The act therefore includes a provision to render the institutional fusion of a university and a HVE institute impossible".

2 The research

This research is aimed at the evaluation of general and specific learning objectives and end-terms for undergraduate science practicals in different institutes of higher education in the Netherlands. In the analysis, the following stages can be distinguished:

- arrangement in order of importance of six general learning objectives for practicals in UE and HVE;
- evaluation of 64 specific learning objectives for practicals by UE and HVE respondents (and their relationship to the six general learning objectives);
- evaluation of 38 end-terms for practicals by UE and HVE respondents;
- comparison of the results of HVE with those of UE;
- comparison of the results of HVE and UE with those of the OuN;
- explicit formulation of the similarities and differences between the three types of institutes.

Before we start to describe the actual research, we will define a number of frequently used concepts.

At the OuN the concept of *practical* is used to indicate a didactic method for learning and practising all the activities involved in the carrying out of one's profession. Primarily in the natural sciences this professional practise entails experimental work, beginning with the conception of a problem or the observation of a phenomenon to the communication of findings in the form of a report or a presentation. Hodson (1988) presents this relationship as follows: experimental work is a subset of laboratory work. He refers to this as *laboratory bench work*. Laboratory work is a subset of practicals, which in turn is a subset of the didactics of science education. Figure 1 gives a schematic representation of this interrelationship.

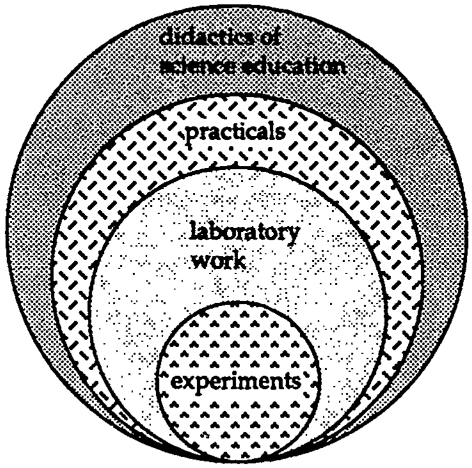

Figure 1
Interrelationship between experiments, laboratory work and practicals (Hodson, 1988)

The *undergraduate* part of an educational programme is the part of the programme that consists of short, well-defined courses that are obligatory for all students (of a certain discipline). In traditional universities, the biology, chemistry and physics programmes comprise approximately 800-1000 hours of undergraduate practicals. Besides this undergraduate part of the programme, approximately 1200 hours have been reserved for work experience or research training. The figures in higher vocational education are 900 hours spread out over three of the four years of study.
The *general learning objectives* have been formulated on the basis of the expected learning results; they have been fitted with a list of achievements that specify the eventual behaviour of the students (the *specific learning objectives*).
The difference between objectives and *end-terms* for practicals can be described as follows: for the attainment of the general and the specific objectives, the execution of practicals is a purpose in itself whereas for the achievement of the end-terms, the execution of practicals, besides many other didactic methods, is a means to an end.

2.1 *Synopsis of the results of the research within the product group Natural Sciences of the OuN*

General learning objectives
The members of the product group Natural Sciences were asked to evaluate eight general learning objectives reflecting the course of an ideal experiment (Kirschner and Meester, 1988). The general objectives were formulated on the basis of the specific objectives that were found in the literature. In the course of the research, as a result of further analysis and reclassification of the specific objectives, two general objectives were excluded so that

six were left. For the motivation behind this decision, the reader may refer to paragraph 5.1. The results of this evaluation are listed in table 1.

Table 1
Ranking of importance of general learning objectives.
1 = most important; 6 = least important

rank	*average score*	*general learning objectives*[a]
1	3.58	-use knowledge and skills in unfamiliar situations (*B*)
2	3.42	-interpret experimental data (*E*)
3	3.08	-design (simple) experiments to test hypotheses (*C*)
4	2.83	-solve problems (*A*)
5	1.42	-clearly describe the experiment (*F*)
6	0.50	-use lab skills in performing (simple) experiments (*D*)

[a] The letters between parentheses correspond with the letters in appendix 5.

A 'paired *t*-test' has demonstrated that a distinction can be made between the first four general objectives, which do not differ from each other statistically ($t \leq 1.68; p > 0.12$) and the last two general objectives ($t \geq 2.2; p < 0.05$).

Specific learning objectives
By means of an inventory (see paragraph 4.2 and appendix 4), the perceived importance of 64 specific learning objectives was assessed by members of the product group Natural Sciences.
Six of the eleven highest rated objectives classified as *indispensable* (see appendix 1) are specifications of the general learning objective *E* 'to interpret experimental data'. As this general objective had been classified as second most important (table 1), a high rating of the specific objectives falling under this objective was to be expected. The other specific objectives falling under this general objective generally also scored high (another three in the 'top twenty').
Among the eleven *indispensable* specific learning objectives are three objectives that have been classified under the general learning objective 'to solve problems'(*A*). The next group of twenty objectives also includes a number of specifications of general objective *A*. This again concurs with the position of this general objective among the four most important objectives. Only two specific learning objectives falling under this general objective feature among the last sixteen, i.e. the least important objectives.
When we take a look at the region of unimportant learning objectives (the last sixteen), we find a total of ten specifications of the general objective *D* 'to use laboratory skills'. There is a clear relationship between the position of general objective *D* at the bottom of the list of general objectives and the little importance attached to the corresponding specific objectives. Apparently the acquisition of practical skills is considered of little importance to natural sciences undergraduates at the OuN.
Among the remaining six objectives are two objectives that are very 'recipe-like'. Appendix 1 shows all the 64 learning objectives together with their perceived importance score.

End-terms
The article by Kirschner & Meester (1988) mentions the following two general end-terms:
I to obtain good (scientific) attitudes
II to understand the scientific method.

Each of these end-terms corresponds to a large number of specifications. Nearly all of the specifications of the end-terms were rated as important to very important by the product group Natural Sciences of the OuN. This is not surprising considering the fact that these are end-terms for an undergraduate study in the natural sciences as a whole, for which practicals are but a means to that end.
The six highest rated specifications all concern higher academic skills. The five lowest rated specifications, on the other hand (see appendix 2), all deal with a more or less 'romantic', unrealistic or idealistic view on undergraduate science practicals.

3 Respondents

For this part of the research, fifty faculties, sectors or departments of universities and higher vocational schools offering education in (a subject area of) the natural sciences were written to with the request to let two instruments (see paragraph 4) and a questionnaire on background information be filled in by the person or persons responsible for practicals within the institute. In order to make the list of institutes to be written to as complete as possible, we made use of the various university guides as well as of the HVE almanac (1988). Of the selected institutes 27 were concerned with university education and 23 with higher vocational education.
All science disciplines (biology, chemistry, physics, geology and environmental science) were represented. Of the HVE institutes addressed there were two institutes for analytical process and laboratory instrumentation, four institutes for biological laboratory work, fifteen institutes for chemical laboratory work and two institutes for environmental science. In UE, six biology, six physics, nine chemistry, four environmental science/hygiene and two geology/earth sciences faculties or departments were approached.
The institutes concerned were solicited according to the following two-step procedure:
- the boards of governors/directors of the various faculties, sectors, departments etc. were written to with the request to pass the instruments sent to them on to either a member of the educational committee or the coordinator of practicals of the institute;
- in addition, the boards of governors/directors were asked to make the names and addresses of the respondents known to us by means of a reply card and a stamped self-addressed envelope, to allow us to contact him/her personally, if necessary.

Of the fifty institutes that were approached, 36 returned the two instruments and the background questionnaire. This is a response of 72%, which is quite a high percentage for questionnaire researches, especially considering the size of the instruments (see appendices 3 and 4). Of the 36 respondents, 14 are working in HVE institutes (response = 61%) and 22 in UE institutes (response = 81%). Table 2 gives a survey of the characteristics of the respondents.

On the basis of the information presented in table 2, we may conclude that:
- most of the respondents work at institutes with monodisciplinary programmes,
- within the institutes for HVE, most of the respondents are not practical coordinators (7%); this differs from UE (36%),
- if one looks at the different institutes approached, the distribution of respondents over the science disciplines is not out of the ordinary,
- none of the geology/earth sciences sectors responded,
- most of those responding have a long record of service in higher education, and
- the distribution of the respondents over members or not-members of an educational committee is not extraordinary.

A number of these characteristics will be used in the analysis of the results.

Table 2
Characteristics of the respondents

Characteristic	*HVE (N=14)*	*UE (N=22)*
Educational programme		
monodisciplinary	12	19
multi-/interdisciplinary	2	3
Practical coordinator		
yes	1	8
no	13	14
Educational committee		
member	9	12
not a member	5	10
Discipline		
chemistry	11	8
physics	1	6
biology	1	5
interdisciplinary	-	3
(not known)	(1)	(-)
Experience in education		
1 - 5 years	2	1
6 - 10 years	2	3
11 - 15 years	6	2
16 - 20 years	2	5
21 - 25 years	1	5
> 26 years	-	3
(not known)	(1)	(3)

4 Research method

4.1 *Instruments*

Three instruments (inventories) were developed. Two of them were used to determine the perceived importance of the learning objectives and end-terms. The third one was used to obtain background information on the respondents.
The first instrument consists of a paired comparison of eight general learning objectives (see appendix 3). These eight general objectives, derived from the article by Kirschner & Meester (1988), are based on the successive steps that a scientist ideally takes when carrying out an experiment.
These are:
- to formulate hypotheses
- to solve problems
- to use knowledge and skills in unfamiliar situations
- to design (simple) experiments to test hypotheses
- to use laboratory skills in performing (simple) experiments
- to interpret experimental data
- to clearly describe the experiment
- to remember the central idea of an experiment over a significantly long period of time.

In the instrument, each of the eight objectives is paired with each of the other seven, yielding a total of 28 pairs of objectives (see appendix 3). Each of these pairs is presented on a separate page of a questionnaire book with a request to the respondent to indicate which of the two objectives, he/she considers most important.

An example of a page:

'After completing their study in the natural sciences, students should be able to:

0 use knowledge and skills in unfamiliar situations
0 interpret experimental data'

The pairs were arranged in such a way that each objective appeared an equal number of times as the first and as the second objective. The objectives were distributed as equally as possible over the inventory, although it turned out to be impossible to prevent the same objective from appearing in two successive pairs. The respondents were requested to start by going through the inventory once before filling it in and, once started, not to leaf forward or backward so that they would not be influenced by previously made choices. We deliberately opted for a comparison in pairs instead of introducing ranking of priority 1 - 8, as has been done in several other studies (Kerr, 1963; Woolnough, 1967; Gould, 1978; Boud et al., 1980; Beatty, 1982). In our view, it is very difficult to rank the eight learning objectives as such, because the differences in importance are usually fairly small. Our instrument forces the respondent to weigh the objectives in each pair against each other, and to choose between them.

The second instrument comprises, in random order, the specific learning objectives and end-terms taken from the same article by Kirschner & Meester. The respondents were asked to indicate the importance of each objective on a five-point Likert scale (see appendix 4). The five scale units range from indispensable to superfluous and have been given the following meaning:

indispensable:	this learning objective is essential and must be included in the program; much emphasis should be placed on this objective
important:	this objective should be included but not necessarily emphasised
neutral:	I don't have an opinion as to this objective; by a vote on such an objective I would abstain
not really necessary:	this objective is of minimal importance; if there is a lack of time or opportunity then this objective need not be included
superfluous:	this objective should not be included in the curriculum; no time need be reserved for this objective

The respondents were again asked to start by reading through all the items once before filling them in and, once started, not to leaf forward or backward or to change answers already given.

Some examples of items from this questionnaire:

'At the end of their study, each student in the natural sciences should be able to:

- make order-of-magnitude calculations and estimates

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

- use the laboratory as an instrument for discovery

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

- use practical (as opposed to theoretical) laboratory skills'

onontbeerlijk	*belangrijk*	*neutraal*	*niet echt nodig*	*vervalt*

Initially, the 97 specific objectives and end-terms of the second instrument were formulated in the same way as in the article of Kirschner & Meester (in random order). On closer consideration - after a draft version of this instrument had been presented to a number of scientists, teaching methodologists and educational experts - several items were found to be vague or open to more than one interpretation. After reformulation, the list of specific learning objectives and end-terms was submitted to a number of educational experts and scientists for evaluation. As a result of this, five items were excluded, six items were split up into two items, two items were split up into three items and many items were reformulated in order to render them as unequivocal as possible. Some items also changed places: a few specific objectives became end-terms and vice versa. The final list consists of 102 items, among which 64 specific learning objectives and 38 specific end-terms. This list was sent to the institutes, as described in paragraph 3.

4.2 *Validity and reliability*

A test or scale is valid (or invalid) for the scientific or practical purpose of its users and not valid (or invalid) in a vacuum. The inventories developed here are *neither* meant for prediction *nor* for the testing of hypothesized relations or theoretical constructs. *Criterion-related validity* and *construct validity* respectively are therefore not of consequence here. What is of consequence is the representativeness of sampling adequacy of the content of a measuring instrument. *Content validity* is guided by the question: "Is the substance or content of this measure representative of the content or the universe of content of the property being measured" (Kerlinger, 1973). Seeing as how the inventories are based upon the most complete set of objectives collected to date (Kirschner & Meester, 1988), the answer to this question is an unequivocal yes.

Two measures of reliability were used for the list of objectives and end-terms and its subscales: Cronbach's α and Guttman's split-half coefficient. Cronbach's α is a reliability measure for internal consistency which gives a unique estimate of the reliability for a single usage. It is based on the ratio between item variances and the variance of the whole. The split-half method, on the other hand, treats one list as if it were two comparable lists (instruments), each of them half the size of the original list. The reliability of the questionnaire as a whole expressed in Cronbach's α is 0.94; the Guttman split-half coefficient is 0.87. When this questionnaire is subdivided into specific learning objectives and end-terms Cronbach's α is 0.91 and 0.88 respectively. Table 3 shows a further itemization of the two reliability measures for the two different respondent groups. For reasons of comparison the results of the OuN will also be presented in the various tables.

Table 3
Reliability measures for the learning objective list of 102 items, itemized according to respondent groups and subscales

	specific objectives (N=64)		*end-terms (N=38)*		*total (N=102)*	
	α	*split half*	α	*split half*	α	*split half*
HVE + UE (*N*=36)	.91	.80	.88	.78	.94	.87
HVE (*N*=14)	.94	.78	.84	.91	.95	.85
UE (*N*=22)	.89	.86	.89	.76	.94	.90
OuN (*N*=12)	.93	.91	.86	.75	.95	.93

The results of the different analyses as presented in table 3 show that the reliability of the instrument and its subscales is high . In other words, the measurements made with the instrument are relatively free of chance.

In order to determine the extent to which the individual orders of priority correspond to each other, the concordance coefficient or Kendall's W has been calculated (Siegel, 1956; Hays, 1981). This coefficient is a measure of the relation among *several* rankings of N objects or individuals (6 learning objectives) and m subjects (the respondents). It expresses thus the degree of association among variables and can vary between the value 0, representing no agreement, and 1 (representing perfect agreement). From a high value of W one may deduce that the respondents have arranged the items on the bases of the same criterion. This does not necessarily mean, however, that the order of priority is 'correct', as each respondent may have used an 'incorrect' criterion for his/her arrangement.

The concordance coefficient, W, is defined as:

$$W = \frac{S}{S_{max}} = \frac{12S}{m^2 (N^3 - N)}$$

in which:

m	= number of respondents
N	= number of general learning objectives
S	= total number of actual differences in the order of priority of objectives between the respondents
S_{max}	= highest possible number of differences in the order of priority of objectives between the respondents

Table 4 shows the values of *W*, as well as the calculated values of X^2 and the corresponding significance levels.

Table 4
Concordance coefficient per (sub)population

	m	*N*	*W*	X^2	*sign.*
HVE	14	6	0.06	4.15	n.s.[a]
UE	22	6	0.08	8.94	n.s.
Biology	5	6	0.24	6.03	n.s.
Chemistry	8	6	0.31	12.45	< 0.05
Physics	6	6	0.21	6.24	n.s.
Monodisciplinary	19	6	0.10	9.97	n.s.
Interdisciplinary	3	6	0.06	0.86	n.s.
OuN	12	6	0.46	27.48	< 0.001

[a] n.s. = not significant; $p > 0.05$

From this we may conclude that, on the whole, HVE and UE are certainly not consistent in their view on the use of practicals in the undergraduate part of educational programmes. In fact, only chemists hold a fairly consistent opinion on the matter.
For the OuN, a high value of *W* was found. This is not surprising, considering the fact the respondents concerned all belong to the same institute and are working together as a close-knit group to give shape to innovative education at the OuN.

5 Results

In this chapter we will first discuss the results of the ranking of the general objectives. Subsequently the results of the evaluation of the specific learning objectives will be discussed and finally the end-terms. Each of these three discussions will start with the results of the universities, which in turn will be subdivided into the results of the different disciplines. Subsequently the results of the HVE institutes will be discussed.

5.1 *General learning objectives*

Before starting with the systematic discussion of the results, attention should be paid to the following. On the basis of the results of earlier research into learning objectives for practicals at the OuN (Meester, Kirschner, Middelbeek and Hermans, 1989), it was decided to discard two of the eight original general objectives. After analysis and rearrangement of the 64 specific learning objectives, it was found that the two general objectives 'to formulate hypotheses' and 'to remember the central idea of an experiment over a significantly long period of time' only corresponded to two and one specifications respectively. These specifications were consequently brought under other general objectives. The two specific objectives concerning the formulation of hypotheses were brought (as component skills) under the general objective 'to solve problems'; the specification of the other general objective under 'to clearly describe experiments'. Although these two original general objectives may be interesting for further analysis from an intellectual point of view, they are uninteresting from a practical point of view. General objectives which cannot be operationalised into one or more specific objectives cannot really be of any importance to education. These two general objectives were therefore left out of the the analysis and discussion of the results. As each of the 28 pairs in the inventory is independent of the other pairs, this decision does not have any consequences for the processing of the results.

The six remaining general learning objectives are:
A to solve problems
B to use knowledge and skills in unfamiliar situations
C to design (simple) experiments to test hypotheses
D to use laboratory skills in performing (simple) experiments
E to interpret experimental data
F to clearly describe the experiment
These six general learning objectives can be found in appendix 5, together with the corresponding specific learning objectives.

5.1.1 *General learning objectives in UE*

In order to gain insight into the evaluation by the respondents of the six general learning objectives, we tallied the number of times that a certain general objective was given preference over another objective, for the entire research population. According to Thurstone (Swanborn, 1982) this is the first step towards the analysis of the response on a comparison in pairs. It allows one to get a first impression of the order of priority. Figure 2 shows the results.

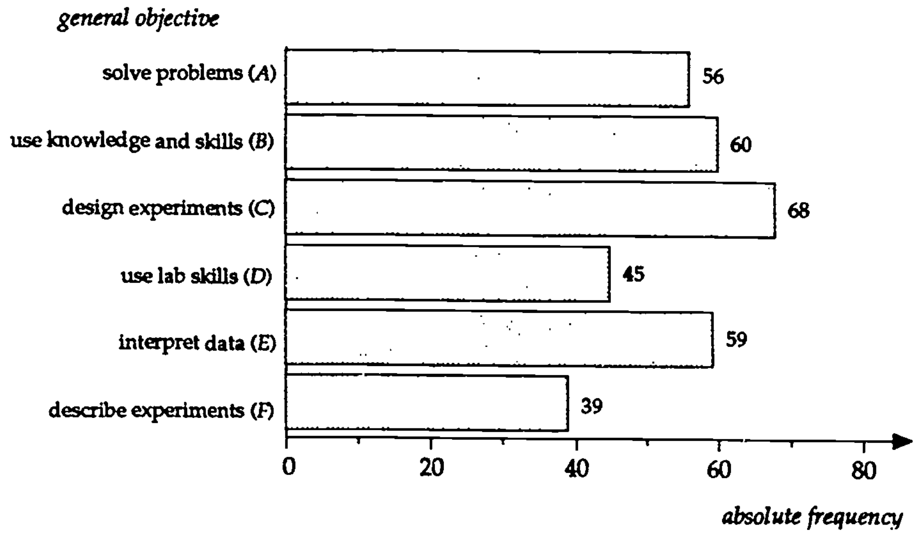

Figure 2
Frequency distribution of the general learning objectives within UE
The maximum frequency is 110

The average scores of the objectives can be obtained by dividing the absolute frequency of each objective by the number of respondents. The highest possible score is five, the lowest possible score zero. In table 5 the general objectives are arranged in order of a decreasing average score, i.e. of decreasing perceived importance.

Table 5
Ranking of general learning objectives for UE in order of decreasing importance

rank[a]	*average score*	*general learning objective*
1	3.09	-to design (simple) experiments to test hypotheses (*C*)
2	2.73	-to use knowledge and skills in unfamiliar situations (*B*)
3	2.68	-to interpret experimental data (*E*)
4	2.55	-to solve problems (*A*)
5	2.05	-to use laboratory skills in performing (simple) experiments (*D*)
6	1.77	-to clearly describe the experiment (*F*)

[a] 1 = most important; 6 = least important

The order of priority with regard to the general objectives as expressed by the respondents from UE institutes is quite subtle (table 5). The difference between the most and least important objective is 1.32, as opposed to 3.08 for the OuN (see table 1). Although some of the scores differ significantly, it is not possible to make a clear distinction between two clusters of objectives, as was the case for the OuN (see paragraph 2.1).
Two important general objectives 'to design experiments to test hypotheses' and 'to interpret experimental data' score significantly higher ($p < 0.05$) than the least important general objective 'to clearly describe an experiment'. The most important objective also scores significantly higher ($p < 0.05$) than the objective 'to use laboratory skills'. Otherwise there are no significant differences.
The evaluations of the three UE disciplines biology, chemistry and physics, are far more pronounced than those for UE as a whole. Table 6 shows the average score and rank of each objective.

For UE as a whole, the difference between the highest and the lowest average of the objectives was 1.32. For the three science disciplines biology, chemistry and physics, much higher figures were found: 2.40, 2.75 and 2.33 respectively. The differences between successive objectives are also far more pronounced for the individual disciplines than for UE as a whole.
A striking result is that solving problems (*A*) is rated as very important by chemists and biologists (rank 1 and 2, respectively), whereas physicists rate this objective as unimportant (rank 6). On the other hand, physicists consider the carrying out of experiments (*D*) important (rank 2), whereas chemists and biologists attach relatively little importance to this objective (rank 5 and 6, respectively). Chemists attach great importance (rank 1) to the use of knowledge and skills in unfamiliar situations (*B*), whereas physicists and biologists rate these objectives as fifth and fourth respectively. This difference may be the result of a fundamental difference between chemists, on the one hand, and biologists and physicists on the other. Chemists attempt to create new substances while biologists and physicists tend to study existing situations.

Table 6
Ranks and average scores of the general learning objectives for the three science disciplines

general learning objective	*biology*		*chemistry*		*physics*		*multi-discipl.*	
	rank	*ave.*	*rank*	*ave.*	*rank*	*ave.*	*rank*	*ave.*
A-solve problems	2	3.20	1	3.63	6	1.00	6	1.67
B-use knowledge and skills in unfamiliar situations	4	2.20	2	3.25	5	2.33	1	3.00
C-design experiments to test hypotheses	1	3.60	3	2.75	1	3.33	3	2.67
D-use laboratory skills in performing experiments	6	1.20	5	1.75	2	3.00	5	2.33
E-interpret experimental data	3	3.00	4	2.38	3	2.83	3	2.67
F-clearly describe the experiment	5	1.80	6	0.88	4	2.50	3	2.67

Within the three UE disciplines, there are also significant differences between the objectives. With the chemists there is a significant difference ($p < 0.05$) between solving problems (*A*) on the one hand and the use of laboratory skills (*D*) and the ability to describe an experiment (*F*) on the other. The ability to describe an experiment even scores significantly lower than the other objectives ($p<0.05$), except for objective *E*, the ability to interpret experimental data.

5.1.2 *General learning objectives in HVE*

The same procedure was followed here as the one described in paragraph 5.1.1. Figure 3 shows the frequency distribution of the general learning objectives.

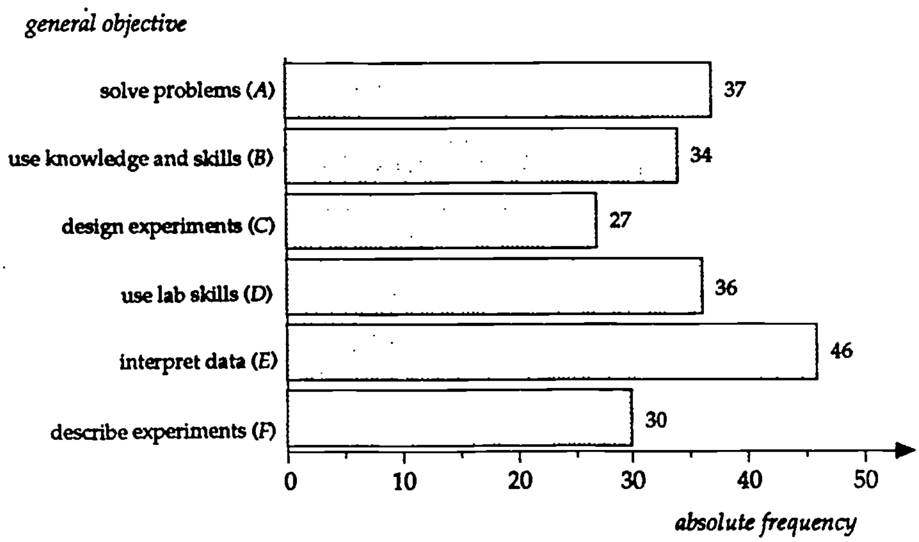

Figure 3
Frequency distribution of the general learning objectives within HVE
The maximum frequency is 70

By analogy with UE, the average scores of the objective were determined. These are shown in table 7.
This table shows that for the HVE respondents there is also a subtle order of priority with regard to the general objectives. Although there is a clear difference between the first and the last objective, the differences between successive objectives are quite small. Only the first objective stands out. The difference between the most and least important objective is 1.36.
Within HVE, the interpretation of data (*E*), the ability to solve problems (*A*) and the use of laboratory skills (*D*) score high, whereas objectives as the ability to describe an experiment (*F*) and the ability to design experiments (*C*) are clearly considered to be of lesser importance.

Table 7
Ranking of general learning objectives for HVE in order of decreasing importance

rank[a]	*average score*	*(UE score)*	*(UE rank)*	*general learning objective*
1	3.29	(2.68)	(3)	-interpret experimental data (*E*)
2	2.74	(2.55)	(4)	-solve problems (*A*)
3	2.57	(2.05)	(5)	-use laboratory skills in performing (simple) experiments (*D*)
4	2.43	(2.73)	(2)	-use knowledge and skills in unfamiliar situations (*B*)
5	2.14	(1.77)	(6)	-clearly describe the experiment (*F*)
6	1.93	(3.09)	(1)	-design (simple) experiments to test hypotheses (*C*)

[a] 1 = most important; 6 = least important

As may be deduced from the average scores, there is only a significant difference between the objective with the highest priority 'to interpret experimental data' (*E*) and the least important objective 'to design experiments to test hypotheses' (*C*) (t=2.17; p<0.05). The differences between the other general objectives are not significant.
The most important difference between the results of HVE and those of UE is the low rating (rank = 6) by HVE respondents of the objective 'to design experiments to test hypotheses' (*C*), whereas this objective scores very high among UE respondents (rank = 1). Comparable, but less pronounced, is the difference in the perceived importance of objective *D* 'the use of laboratory skills in performing experiments'. This general objective is rated third by HVE and fifth by UE.

5.2 *Specific learning objectives*

The second instrument was a Likert scale inventory on the specific learning objectives and the end-terms. For analysis and discussion purposes, this list was divided into a list with specific learning objectives and a list with specific end-terms. Appendices 6 and 7 give a survey of the results of the specific learning objectives sublist arranged in order of decreasing importance for UE and HVE institutes respectively. Besides the average value (x) and standard deviation (*s.d.*), a normalized score (Z) has been given for each objective. This score makes it easier to compare the results of UE, HVE and OuN with each other. This Z-score is based on the averages of the 64 specific objectives and indicates how many standard deviations an objective is removed from the total average score (Z = 0) on basis of its average score.
Table 8 shows the frequency distribution of the specific objectives in the different categories for UE, HVE and the OuN respectively.

Table 8
Frequency distribution of 64 specific learning objectives arranged in order of decreasing importance

type of institute	*number of respondents*	*1*[a]	*2*	*3*	*4*	*5*
UE	22	23 (36%)	33 (52%)	8 (13%)	-	-
HVE	14	28 (44%)	22 (34%)	12 (19%)	2 (3%)	-
OuN	12	11 (17%)	37 (58%)	10 (16%)	6 (9%)	-

[a] 1 = indispensable ($1.00 \leq x < 1.80$); 2 = important ($1.80 \leq x < 2.60$); 3 = neutral ($2.60 \leq x < 3.40$); 4 = not really necessary ($3.40 \leq x < 4.20$); 5 = superfluous ($4.20 \leq x \leq 5.00$)

A striking aspect of this table is the large number of objectives classified as *indispensable* by all the respondent groups, especially by the group of UE respondents (88% of the specific learning objectives), whereas the categories *not really necessary* and *superfluous* are almost empty for HVE and UE. This is not really surprising, given the fact that list of specific objectives is based on literature on objectives for practicals in traditional undergraduate science education (Kirschner and Meester, 1988).

5.2.1 *Specific learning objectives in UE*

When we look at the list of ratings of the specific learning objectives for all UE institutes (appendix 6) it appears that the *s.d.* shows a remarkable trend. The *s.d.* for the objectives which were rated important is clearly lower than 1.0, whereas for the neutral objectives the *s.d.* is almost always approximately equal to 1.0. One might draw the conclusion that the various respondents agree fairly well on the type of objective they consider very important but that their views regarding the objectives classified in category 3 diverge to a much larger extent. A similar tendency in standard deviations had been observed for the classification of the specific learning objectives at the OuN (Meester et al., 1989).

When we look at the 23 specific objectives belonging to the category *indispensable* ($1.00 \leq x < 1.80$) it is obvious that a number of objectives (6) are relevant to the actual understanding of the purpose of the experiment and to activities prior to the execution of the experiment, a number of objectives (5) deal with the actual execution of the experiment and the remaining objectives (12) relate to the processing and analyzing of experimental data and the making of a written report of the experiment. In table 9 the successive stages have been indicated with the headings 'prior to the experiment', 'during the experiment' and 'after the experiment'.

In conclusion we can say that the following learning objectives in particular are highly valued by UE: to understand the purpose of the experiment or of what is to be measured, to carry out the experiment safely and accurately, to evaluate the experimental outcome with regard to accuracy and the expected results (hypothesis) and to describe these results. At the bottom of the list of specific objectives (appendix 6) it is rather striking to see that the design of relevant observation and measurement techniques does not belong to the important objectives of undergraduate UE practicals. The objectives least strived for are 'to confirm facts, principles and theory from lectures and books' and 'to confirm already known facts and laws'.

Table 9
The 23 *indispensable* learning objectives of the UE distributed in accordance with three consecutive stages

Specific learning objective	*x*	*s.d.*
prior to the experiment		
-understand the purpose of an experiment	1.32	0.48
-understand what is to be measured in an experiment	1.36	0.58
-properly plan an experiment	1.50	0.51
-recognize hazards so as to take safety precautions	1.50	0.80
-understand measurement of different phenomena	1.73	0.63
-make order-of-magnitude calculations and estimates	1.77	0.61
during the experiment		
-conduct experiments safely	1.32	0.48
-carry out accurate measurements	1.59	0.59
-observe phenomena in a quantitative way	1.64	0.49
-use practical (as opposed to theoretical) lab skills	1.64	0.66
-collect experimental data	1.64	0.66
after the experiment		
-interpret reliability and meaning of results	1.36	0.49
-present essentials of an experiment in written form	1.36	0.49
-communicate experimental findings in written form	1.41	0.50
-assess relevance of experimental data with regard to a hypothesis	1.50	0.67
-analyze experimental data to draw conclusions	1.55	0.61
-evaluate experimental outcome with respect to a hypothesis	1.59	0.50
-evaluate contribution direct to derived errors	1.62	0.74
-evaluate difference between expected and actual results	1.68	0.57
-process experimental data	1.73	0.55
-describe central aspects of an experiment	1.73	0.55
-apply elementary notions of statistics	1.73	0.77
-summarize an experiment based on results	1.76	0.70

In accordance with the background of the respondents UE analyses have been done on the basis of:

- discipline: biology, chemistry or physics, because we expect a biologist to have different views on practicals than a chemist whose views will be different from those of a physicist (appendixes 8, 9 and 10)
- whether mono- or multidisciplinary education is being offered, because we presume that the pursued learning objectives of practicals are subject to a particular type of educational programme (appendixes 11 and 12)
- whether the respondent coordinates practicals for an institute or not; this might influence the perceived importance of various aspects of practicals (appendices 13 and 14).

Table 10 represents the frequency distribution of the specific learning objectives for the various groups of respondents.

If we compare the disciplines biology, chemistry and physics with each other, it appears that physics shows the largest deviation. The group of objectives in the categories *neutral* and *not really necessary* is considerably larger here than for the two other disciplines.

Table 10
Frequency distribution of specific learning objectives in order of decreasing importance, itemized in accordance with the background of the respondents

background respondents	*number of respondents*	*1*[a]	*2*	*3*	*4*	*5*
UE-biology	5	27	30	7	-	-
UE-chemistry	8	26	28	10	-	-
UE-physics	6	18	27	15	4	-
UE-monodiscipl.	19	24	33	7	-	-
UE-multidiscipl.	3	23	20	19	2	-
UE-pract.coord.	8	25	31	8	-	-
UE-non-pr.coord.	14	25	28	11	-	-

[a] 1 = indispensable ($1.00 \le x < 1.80$); 2 = important ($1.80 \le x < 2.60$); 3 = neutral ($2.60 \le x < 3.40$); 4 = not really necessary ($3.40 \le x < 4.20$); 5 = superfluous ($4.20 \le x \le 5.00$).

Table 11
Evaluations by biologists and chemists of the specific learning objectives which were rated neutral or not really necessary by physicists

specific learning objective	*categ. by biol.*[a]	*categ. by chem.*	*categ. by phys.*
-solve difficult scientific problems	2	3	4
-confirm already known facts and laws	3	3	4
-solve problems in a multi-solution situation	2	2	4
-confirm facts, principles and theory from lecture/books	3	3	4
-incorporate unexpected experimental results in a new model	2	3	3
-handle waste safely	1	1	3
-develop measurement techniques	3	3	3
-follow instructions	3	2	3
-be flexible in modifying experiments	2	2	3
-discuss results with other scientists	2	3	3
-identify variables and determine empirical relations	3	2	3
-recognize and define scientific problems	2	3	3
-construct models which fit experimental evidence	1	2	3
-communicate experimental findings in oral form	1	2	3
-design relevant observation techniques	2	3	3
-translate conceptual definition into a set of measurement procedures	2	3	3
-construct models based on experimental findings	2	2	3
-derive testable hypotheses from theories	1	2	3
-calibrate instruments	2	3	3

[a] 1 = indispensable; 2 = important; 3 = neutral; 4 = not really necessary

A more careful examination of the lists of specific objectives for the three disciplines shows that the 19 objectives which the physicists rated as *neutral* or *not really necessary*, were often rated (much) higher by biologists and chemists (see table 11).
The largest differences can be found between physics and biology; chemistry occupies an intermediate position. The differences are largely attributable to the uniqueness of the various disciplines. 'To handle waste safely' for instance is more important for and is likely to occur more often during biology or chemistry practicals than during physics practicals. Biology and to a lesser extent chemistry attribute an important role to the deduction of hypotheses and the construction of models which link up with the experimental results. Higher academic skills such as 'to solve difficult scientific problems' and 'to solve problems in a multisolution situation' are rated considerably higher by biology respondents than by their physics colleagues. The opinions of the three groups clearly diverge with regard to the importance of the objective 'to communicate experimental findings in oral form'.
It is also interesting to see which of the learning objectives evaluated as *neutral* by the disciplines biology and chemistry, are rated higher by physics. Five of the seven objectives rated *neutral* by biology coincide with *neutral* objectives of physics. Not surprisingly the remaining two objectives namely 'to manipulate apparati' and 'to handle modern equipment' score fairly high (in category 2) for both chemistry and physics. The ten neutral objectives for chemistry are also found amongst the neutral objectives for physics.

Any comments on the results with respect to the type of education offered (monodisciplinary or multi/interdisciplinary) call for a great deal of prudence. Only three respondents originate from institutes offering multi/interdisciplinary education. Because one reason for our research is to investigate the role of monodisciplinary vs. multi-/interdisciplinary programmes, we provide the actual figures, although no conclusions will be drawn from them (see table 10). Suffice it to say that respondents from multi-/interdisciplinary institutes place a larger number of objectives in the categories 3 (*neutral*) and 4 (*not really necessary*) than respondents of monodisciplinary institutes. In this respect the outcome resembles the outcome for the OuN respondents (see table 8).

Analysis of UE results according to whether or not respondents are coordinators of practicals, results in almost equal numbers of specific learning objectives in the various categories (see table 10).
Closer examination of the objectives in the category *indispensable* shows that 21 of the 25 objectives match. Of the nonmatching objectives in this category the objectives in table 12 reveal striking deviations. This is expressed as ΔZ, where Z is the normalized score for an objective. It is a measure of the distance of the average score for a certain objective from the average score of all of the objectives for a certain sample of a population, and is equal to the difference between the averages divided by the standard deviation of the sample.
A striking result is that coordinators of practicals show less interest in the ability of students to understand and follow instructions and with the safe handling of wastes than their non-coordinating colleagues ($\Delta Z < -1$). This may be the result of a certain sobriety on the part of those who coordinate practicals with respect to these subjects. In other words, they are used to labs and are thus less impressed by them. Non-coordinators also stress the qualitative observation of phenomena far more than their coordinating colleagues. It is not really surprising to see that those who coordinate practicals set more store by the ability to handle modern equipment than those who do not ($\Delta Z > 1$).

Table 12
Specific learning objectives evaluated significantly different way by respondents who coordinate practicals and those who do not coordinate practicals

specific learning objective	pract. coord. Z	nonpract. coord. Z	ΔZ
-understand lab instructions	-0.87	1.19	-2.06
-follow instructions	-1.91	-0.48	-1.43
-handle waste safely	-0.34	0.92	-1.26
-observe phenomena in a qualitative way	-0.60	0.75	-1.09
-handle modern equipment	0.45	-0.75	1.20

Comparison of the ten least important learning objectives between coordinators of practicals and those who do not coordinate practicals, shows average values which are fairly close to each other with the exception of the previously mentioned objective 'to understand lab instructions'.
Considering the results, we may state that the difference in the evaluation of specific learning objectives by respondents who do or do not coordinate practicals is not very large.

5.2.2 *Specific learning objectives of HVE institutes*
The tendency in the standard deviations observed in UE in the rating of the objectives and also occurring in the OuN is less obvious in the classification of the specific learning objectives in vocational education (see appendix 7). Apparently the opinions regarding the importance of the objectives differ more widely here than in case of UE and the OuN. This is possibly the result of the fact that the specific objectives were gleaned from literature on university undergraduate practicals.
The distribution of the specific objectives over the categories 1 through 5 (see table 8) is slightly different for HVE institutes than for UE; the category *neutral* contains more objectives and there are even two not really necessary objectives (category 4).
Similar to UE, the *indispensable* specific learning objects - 28 in total (with $1.00 \leq x < 1.80$) - may be classified as occurring 'prior to the experiment' (7), 'during the experiment' (10) and 'after the experiment' (11). This is shown in table 13.
The number of *indispensable* learning objectives relevant to the carrying out of an experiment is much larger here than for UE. This is in accordance with the nature of HVE education. After the experiment attention is focused on processing the experimental data, on applying elementary notions of statistics and on communicating experimental findings in written and oral form. The evaluation of the experimental data to test hypotheses is not considered *indispensable*, as was the case in UE.

The ordered list of specific objectives (appendix 7) ends with two *not really necessary* objectives, 'to solve difficult scientific problems' ($x = 3.64$) and 'to recognize and define scientific problems" ($x = 3.43$). The scores of UE institutes (on the whole) for these two objectives were 3.00 (category 3) and 2.41 (just above the division between category 2 and 3) respectively, which is also not very high. These objectives are probably too advanced for undergraduate practicals. Table 11 shows that only biology respondents value these two objectives as being important.
A subsequent examination of the twelve specific learning objectives on the HVE list in the *neutral* category shows that nine of these are objectives requiring students to design an experiment or to derive hypotheses (models). Apparently a qualified HVE student is not expected to master these skills.

Table 13
The 28 *indispensable* specific learning objectives of HVE, distributed according to three consecutive stages

specific learning objective	x	s.d.
before the experiment		
-understand what is to be measured in an experiment	1.29	0.47
-understand lab instructions	1.36	0.84
-understand the purpose of an experiment	1.50	0.65
-recognize hazards so as to take safety precautions	1.50	0.85
-properly plan an experiment	1.57	0.51
-understand scope and limits of experimental techniques used	1.57	0.65
-make order-of-magnitude calculations and estimates	1.64	0.63
during the experiment		
-collect experimental data	1.21	0.43
-put basic laboratory techniques to use	1.36	0.84
-conduct experiments safely	1.36	0.84
-carry out accurate measurements	1.43	0.65
-observe phenomena in a qualitative way	1.57	0.76
-manipulate apparati	1.57	0.85
-use practical (as opposed to theoretical) lab skills	1.64	0.84
-keep a day-to-day diary	1.64	1.15
-handle waste safely	1.71	0.91
-calibrate instruments	1.71	1.14
after the experiment		
-present essentials of an experiment in written form	1.21	0.43
-interpret reliability and meaning of results	1.36	0.50
-communicate experimental findings in written form	1.50	0.52
-apply elementary notions of statistics	1.50	0.52
-summarize an experiment based on results	1.64	0.50
-evaluate contribution direct to derived errors	1.64	0.63
-analyze experimental data to draw conclusions	1.71	0.61
-communicate experimental findings in oral form	1.79	0.58
-process experimental data	1.79	0.58
-describe central aspects of an experiment	1.79	0.70
-evaluate difference between expected and actual results	1.79	0.80

5.3 *End-terms*

Appendices 15 and 16 give a survey of the 38 end-terms in order of (decreasing) importance for UE and HVE institutes respectively. Here too, the average value (x), the standard deviation (*s.d.*) and the normalized score (Z) are given.
Table 14 gives the distribution of the end-terms for the various educational institutes over the different categories. The outcome of the OuN has been included here as well (Meester et al., 1989).

Table 14
Frequency distribution of 38 end-terms in order of decreasing importance

type of institute	*number of respondents*	*1*[a]	*2*	*3*	*4*	*5*
UE	22	3 (8%)	23 (61%)	12 (32%)	-	-
HVE	14	5 (13%)	17 (45%)	16 (42%)	-	-
OuN	12	6 (18%)	18 (47%)	13 (34%)	1 (3%)	-

[a] 1 = indispensable ($1.00 \leq x < 1.80$); 2 = important ($1.80 \leq x < 2.60$); 3 = neutral ($2.60 \leq x < 3.40$); 4 = not really necessary ($3.40 \leq x < 4.20$); 5 = superfluous ($4.20 \leq x \leq 5.00$).

The table provides a picture that coincides well with the outcome of the specific learning objectives (table 8): the various institutes evaluate the majority of the end-terms as *indispensable* or *important*, a relatively large part is rated *neutral* and only one single end-term is rated as *not really necessary.*

5.3.1 *End-terms in UE*

Of the 38 end-terms only three are assessed as *indispensable* (see table 15 and appendix 15). Two of those relate to higher academic skills. The third one -'to do experiments' - reflects the importance attributed to experimenting within traditional UE.

Table 15
End-terms considered indispensable by UE

specific end-term	*x*
-have a critical attitude to experimental results	1.45
-solve problems in a critical, academic way	1.64
-do experiments	1.73

If we itemize UE respondents according to discipline (appendices 17, 18 and 19), it appears that biologists consider a much larger number of end-terms to be *indispensable* than physicists: biologists place 31 of the 38 end-terms in the categories *indispensable* and *important*, against 22 end-terms for chemists and only 16 for physicists (table 16). It is obvious that chemistry again occupies an intermediate position in this respect. Physics puts more than half of the end-terms (21) in the category *neutral.* For the specific learning objectives we noticed a similar outcome (table 10).

Table 16
Frequency distribution of end-terms in order of decreasing importance for the various disciplines within UE institutes

discipline	*number of respondents*	*1*	*2*	*3*	*4*	*5*	
UE-biology	5	13	18	5	2	-	(appendix 17)
UE-chemistry	8	6	16	16	-	-	(appendix 18)
UE-physics	6	1	15	21	1	-	(appendix 19)

Table 17 indicates the ratings of the other disciplines for the end-terms put in the categories *neutral* and *not really necessary* by physics.

Table 17
Biology and chemistry respondent evaluations of the end-terms rated *neutral* and *not really necessary* by physics respondents

specific end-term	*categ. by biol.*[a]	*categ. by chem.*	*categ. by phys.*
-concretize theoretical notions	2	3	3
-experience spirit and essence of scientific inquiry	1	2	3
-work in research and development labs	2	2	3
-approach a problem with an open mind	1	2	3
-survey literature relevant to some problem	2	2	3
-be interested in the subject area	1	2	3
-intuitively understand scientific phenomena	4	3	3
-use the lab as an instrument for discovery	1	1	3
-tackle a problem without help of others	3	3	3
-determine limits under which a theory applies	2	3	3
-formulate a problem that can be researched	1	2	3
-experience past and present scientist's joy	2	3	3
-work independently of others	3	3	3
-be self-confident and independent	4	3	3
-take active part in the process of science	1	3	3
-use motor skills inherent to professionals	3	3	3
-work in groups to solve scientific problems	2	2	3
-experience kinship with the scientist	3	3	3
-illustrate facts, princ. and theory of lectures/books	2	2	3
-appreciate the usual and unusual	2	3	3
-experience joys and sorrows of experimenting	2	3	3
-build a framework for facts, principles and theory from lectures/books	3	3	4

[a] 1 = indispensable; 2 = important; 3 = neutral; 4 = not really necessary

Table 17 illustrates once more that the evaluations of biology and physics respondents differ most. Six end-terms have been rated *neutral* by physicists and *indispensable* by biologists. It should be noted, however, that all end-terms placed in the categories 3 and 4 by biology respondents (a total of 7) are placed in the same categories by physics and chemistry respondents.
Of the 16 *neutral* end-terms for chemists, 12 correspond to the *neutral* end-terms of physics. One of the end-terms is even rated by the physicists as being *not really necessary*. Three of the end-terms which were given a higher evaluation by the physicists ($x = 2.50$) are only slightly higher than the category *neutral*, so there are no striking differences.

It is also interesting on the other hand to observe which end-terms are considered *indispensable* by biology and to compare the outcome with the position they occupy within the other disciplines (table 18). It is interesting to note that the four end-terms with the highest scores are related to the ability to formulate and solve (scientific) problems.

Table 18
Chemistry and physics evaluations of end-terms considered *indispensable* by biology respondents

specific end-term	*categ. by biol.*[a]	*categ. by chem.*	*categ. by phys.*
-formulate a problem that can be researched	1	2	3
-solve problems in a critical, academic way	1	1	2
-make decisions in a proper course of action of problem solving	1	2	2
-approach a problem with an open mind	1	2	3
-use the lab as an instrument for discovery	1	1	3
-deeply understand the discipline studied	1	1	2
-approach observed phenomena from a scientific point of view	1	2	2
-be interested in the subject area	1	2	3
-experience spirit and essence of scientific inquiry	1	2	3
-have a critical attitude to experimental results	1	1	1
-form attitudes related to value and uses of experimental science	1	1	2
-take active part in the process of science	1	3	3
-do experiments	1	1	2

[a] 1 = indispensable; 2 = important; 3 = neutral

The biology respondents place all of the six end-terms considered *indispensable* by chemistry in the same category as the latter. Only the end-term 'to have a critical attitude to experimental results' is qualified as *indispensable* by each one of the three groups of respondents. Table 18 makes the intermediate position occupied by the chemistry respondents quite obvious.

5.3.2 *End-terms of HVE institutes*

Table 19 shows the five end-terms with the highest evaluations as they appear from the HVE research (see appendix 16). Not surprisingly the end-term 'to do experiments' was valued as the most important. Of the five end-terms rated *indispensable* it should be noted that the first four correspond to a number of essential aspects of the practical education provided by these institutes: to survey literature relevant to the problem should take place prior to experimenting. Proper planning and having a critical attitude to experimental results, are considered highly important in the performing of experiments.
Of the five *indispensable* end-terms, 'to do experiments' and 'to have a critical attitude to experimental results' concur with UE.

Close examination of the 16 *neutral* end-terms (appendix 16) reveals that the end-terms concerned pertain primarily to the student's attitude towards science and scientific work, to the way in which both aspects are experienced and to certain academic skills.

Table 19
End-terms considered indispensable for HVE practicals

specific end-term	*x*
-do experiments	1.36
-have a critical attitude to experimental results	1.43
-plan ahead	1.71
-survey literature relevant to some problem	1.79
-be interested in the subject area	1.79

6 Discussion

As with the results, the discussion will first focus on the general objectives, then the specific objectives and finally the end-terms.

6.1 *General learning objectives*

When drawing conclusions from the results of the general learning objectives we must take into account that there is no clear agreement among the respondents from the various subgroups. The chemists were the only ones manifesting a high degree of concordance. Nevertheless it should be possible to indicate some differences of opinions about and tendencies with respect to general objectives of undergraduate practicals.

6.1.1 *General learning objectives: HVE compared to UE*

For HVE, data interpretation (*E*) was by far the most important and the design of experiments to test hypotheses (*C*) the least important general objective. These results are not very surprising. To collect, process, and interpret data (including the ability to make order of magnitude calculations, to evaluate measurement errors and to assess the reliability of experimental data) is very important in a type of education which focuses on training people who should be capable of setting up and carrying out experiments for the solution of concrete problems. To derive hypotheses from theories and (subsequently) to design experiments in order to test these hypotheses is not typically focused on in a practically oriented institute such as those for higher vocational education.

For universities on the other hand, we see that the development of an experiment to test hypotheses (*C*) is considered the most important general objective. A university education aims to achieve academic skills in its students so that they can become independent practitioners in their field of scientific study. UE has its task in training people to become critical scientists capable of academic thinking, who can apply their knowledge in different, often unique, situations. UE students therefore have to learn to recognize and define problems, to analyze parts of those problems, to determine strategies to solve the (part of the) problems, to carry out these strategies (or to have others carry them out) and to assess the ensuing results in order to determine the degree to which the original (part of the) problems have (has) been properly solved. White (1988) calls this possessing cognitive strategies. These are non-subject-specific general skills connected to the ability to assess a situation, to plan the necessary course of action and to process the ensuing data or information in connection with the original situation. Given the preceding arguments, one of the two objectives considered least important by UE respondents could have been anticipated; the other one not.

The use of laboratory skills to carry out (simple) experiments (objective *D*, the second least important) hardly deserves priority in academic education. Nowadays scientists spend most of their time behind an office desk or computer and not in a laboratory. Research projects reserve money and space for technicians, analysts, laboratory assistants etc. often originating from HVE and specially trained to carry out experiments.

The low score, for both UE and HVE institutes, of general objective *F* 'to clearly describe the experiment' is quite surprising, because the publication of research results in scientific magazines and the presentation of results at congresses and conferences is quiet common in scientific circles. This result is even more surprising if one considers the high score of the specific objectives which are part of this general objective and in particular those specifications relating to written communicative skills (see paragraph 5.2.1). This discrepancy may be the result of the use of the verb 'to describe'. According to the various taxonomies of objectives (Bloom et al., 1956; Gronlund, 1970; Klopfer, 1971) 'to describe' can be interpreted in two ways. According to Bloom the verb first of all fits in the lowest category of objectives within the cognitive domain namely the category of knowledge objectives. Characteristic verbs are: to reproduce, to remember, to recognize, to describe, to enumerate, etc. The emphasis is on remembering or spontaneously recognizing subject matter, facts, definitions, connections and methods.
Apart from this interpretation as a 'low' cognitive objective, it is also possible to interpret the verb as a relatively 'high' cognitive objective. In this respect the word to describe is used in the sense of synthesizing. Synthesis is the ability to put parts together to form a new whole. This may involve the production of a unique communication (theme or speech), a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information)' (Bloom, 1956). Here, emphasis is put on creative behaviour; the creation of new patterns or structures. According to Gronlund (1970) objectives such as the ability to develop a proper line of reasoning, the ability to give a good lecture or the ability to summarize the essentials of an experiment belong to the category synthesis. Apparently the respondents, like the respondents of the OuN, have interpreted the general objective in the sense of low cognitive, especially in comparison with the other general objectives. By contrast, the specific objectives relating to communicative skills are interpreted as higher, more creative and therefore both UE institutes and HVE institutes count them among the *indispensable* objectives.

Within the three responding natural science disciplines there are a number of differences which should be noted (see table 6). Physicists do not seem to attach much value to the ability to solve problems (*A*; rank 6) and the ability to use knowledge and skills in unfamiliar situations (*B*; rank 5). Objective *A* is highly valued by both chemists and biologists (rank 1 or 2 respectively).
The reason for this might be explained by the differences in nature of the undergraduate practicals within the different disciplines. According to Conway, Mendoza and Read (1963), Reif and St. John (1979) and Read (1969) physics practicals are especially concerned with the verification and the replication of 'classical' experiments often in order to rediscover and/or to reconfirm what has already been discovered. According to Robinson (1979) the reason for this could be that the apparati present in the practicals for physics are "frequently antiquated or else is of the 'educational' variety having only a vague resemblance to that found in modern laboratories where *real* problems are being solved and *real* discoveries are being made (p. 859)".
An alternative explanation might be that there is a great difference in didactic tradition between the disciplines of chemistry and physics (Zuur, 1990). Physicists accentuate the reproduction of phenomena in order to achieve accurate measurements (quantitative tradition) while chemists and biologists accentuate the production or discovery of new substances or phenomena (qualitative tradition). With respect to this it is not strange that the disciplines biology and chemistry rate the objective 'to solve problems' much higher than physics, because the apparati at their disposal are more closely related to the *real situation* and perhaps there is also more opportunity for open qualitative work.
Objective *B* is not valued highly either by the biologists (rank 4) but the chemists have given it a high priority (rank 2).

6.1.2 *General learning objectives: OuN compared to UE and HVE*

Apart from examining UE and HVE separately and comparing them to one another, we can also compare the OuN with both HVE and UE (and separate UE disciplines). The average scores of the six general learning objectives have been given in tables 1, 5, 6, and 7. By taking the OuN each time as the point of departure, except for comparisons between UE and HVE, we can indicate the difference in the average scores (Δx) (see table 20). If the difference is positive it means that a general objective is considered much more important in the first mentioned institute than in the second. If the difference is negative it implies that a general objective is considered less important in the first mentioned institute than in the second.

Table 20
The difference in the averages (Δx) for the general learning objectives when comparing the various institutes. Values with a $\Delta x > 1$ or < -1 are printed in bold letters

general objective	*OuN-HVE*	*OuN-UE*	*HVE-UE*	*OuN-bio*	*OuN-che*	*OuN-phy*
A-solve problems	0.19	0.28	0.09	-0.37	-0.80	**1.83**
B-use knowledge and skills in unfamiliar situations	**1.15**	0.85	-0.30	**1.38**	0.33	**1.25**
C-design experiments to test hypotheses	**1.15**	-0.01	**-1.16**	-0.52	0.33	-0.25
D-use laboratory skills in performing experiments	**-2.07**	**-1.55**	0.52	-0.70	**-1.25**	**-2.50**
E-interpret experimental data	0.13	0.74	0.61	0.42	**1.04**	0.59
F-clearly describe the experiment	-0.73	-0.35	0.37	-0.38	0.52	**-1.08**
sum of the absolute differences: $\Sigma\|\Delta x\|$	5.41	3.78	3.05	3.77	4.27	7.50

The following results are of interest:

- The number of general objectives in which the OuN and HVE differ greatly (*B*, *C* and *D*) is larger than that number between the OuN and UE (*D*). Both UE and HVE consider the use of laboratory skills much more important than the OuN. More than HVE, the OuN sets great store by the use of knowledge and skills in unfamiliar situations and the ability to design experiments to test hypotheses.
- UE and HVE differ, as noted earlier, to a large extent with regard to one single objective 'the ability to design experiments to test hypotheses' (*C*). Otherwise the differences are slight.

These results tend to the conclusion that, with regard to the general learning objectives for undergraduate practicals, the difference between the OuN and HVE is much larger than the difference between UE and HVE. This is probably the result of the highly specific character of the OuN which focuses on and strives to provide 'a type of education which enables its graduates to learn to think in a problem oriented manner (End-terms, 1986). In other words, what the OuN graduate misses in laboratory skills is/must be more than compensated by training in problem oriented and problem solving thinking.
The differences between the various institutes of higher education is most clear when we look at the sum of the absolute differences (last row of table 20). The smallest difference is between HVE-UE and the largest is between OuN-HVE. The OuN therefore differs more

from HVE and UE than HVE from UE! This topic will be discussed further in paragraph 6.2.3.
Table 20 also gives the differences between the OuN and the three separate disciplines. The OuN differs least from biology (only objective *B* is considered much more important by the OuN), to a slightly greater degree from chemistry (OuN considers objective *D* much less important and objective *E* much more important than the chemists) and from physics the OuN differs with regard to four of the six objectives (objectives *A* and *B* are more important for the OuN; the objectives *D* and *F* are more important for physics). This tendency is also reflected in the total of the absolute differences: the OuN and biology differ the least (although there is still a difference of 3.77), OuN and chemistry differ slightly more (4.27) and the most between OuN and physics (7.50).

6.2 *Specific learning objectives*

Drawing conclusions from the results of the specific learning objectives requires special care. There is a certain degree of subjectivity with regard to the interpretation of each specific objective. This study can only indicate a tendency in objectives which are considered more or less important as well as indicate to which general learning objectives these specific objectives correspond. It is almost impossible to achieve a one-tc ɔne correspondence, because occasionally a certain specific learning objective might be considered to belong to several general objectives.
The distinction between specific learning objectives and end-terms is also not always unequivocal. We consider 'to solve difficult scientific problems' for instance to be an objective because we interpret it as the ability to solve problems, partly prior to an experiment. However this could also be considered as an end-term of a study of the natural sciences. Despite the above mentioned interpretation problems we are of the opinion that it is safe to analyze the results of the specific objectives and to draw conclusions from this analysis.

6.2.1 *Specific learning objectives versus general learning objectives*

The subsumption of each of the specific objectives to one of the six general objectives was presented in a previous article by two of the present authors. This classification is, of course, open to discussion. It is, thus, interesting to use the results of this research to check as to whether or not there is any empirical basis for the classification.
One way to do this is by calculating Cronbach's α, a measure of reliability, for the specifications of each of the general objectives. Cronbach's α is a measure of homogeneity between the variance of the separate objectives and the variance of the scale (each general objective) as a whole (see paragraph 4.2). Table 21 shows the value of α for each of the general objectives. In calculating the scores, we used the responses from the OuN, UE, and HVE together to achieve a maximum sample size.
This table gives a strong indication that the specifications of the general learning objectives as defined in Kirschner & Meester (1988) and revised in Meester et al (1990) are fairly homogenous and that the classification is very well plausible. Only the objective 'to solve problems' (*A*) has a rather low α (0.48).

Table 21
Cronbach's α for the specifications of the general learning objectives

general learning objective	*number of specifications*	*Cronbach's α*
A-solve problems	10	0.48
B-use knowledge and skills in unfamiliar situations	6	0.77
C-design experiments to test hypotheses	8	0.77
D-use laboratory skills in performing experiments	17	0.91
E-interpret experimental data	16	0.73
F-clearly describe the experiment	7	0.69

In order to determine whether a relationship exists between perceived importance of the general objectives and the ratings of their constituent specific objectives we calculated an average *Z*-score for each group of specifications. We arrived at this score by summing up the *Z*-scores for all of the specific objectives belonging to a general objective and dividing this by the number of specifications.
The average *Z*-scores for the different groups of respondents are given in table 22.

Table 22
Average *Z*-scores for the specifications of every general learning objective and the differences between them for the different response groups

general learning objective	*OuN*	*HVE*	*UE*	*OuN-HVE*	*OuN-UE*	*HVE-UE*
A-solve problems	+0.39	-0.50	-0.15	+0.89	+0.54	-0.35
B-use knowledge and skills in unfamiliar situations	+0.42	-1.07	-0.43	+1.49	+0.85	-0.64
C-design experiments to test hypotheses	-0.21	-0.49	-0.18	+0.28	-0.03	-0.46
D-use laboratory skills in performing experiments	-0.85	+0.59	+0.07	-1.44	-0.92	+0.52
E-interpret experimental data	+0.43	+0.10	+0.12	+0.33	+0.31	-0.02
F-clearly describe the experiment	+0.40	+0.55	+0.36	-0.15	+0.04	+0.19

It is evident that the largest differences between the OuN on the one hand and HVE and UE on the other are for the general objectives *B*, *D* and (to a lesser degree) *A*. For all of the general learning objectives HVE differs from the OuN to a greater extent than it does from UE. As stated earlier, the OuN finds the use and development of laboratory skills (*D*) much less important than does HVE and UE. The OuN, on the other hand, deems objectives dealing with the use of knowledge and skills in unfamiliar situations (*B*) and solving problems (*A*) as being more important than the other institutions.

There are noticeably fewer differences between HVE and UE. While there is a large difference in the rating given to general objective *C* in the paired comparison, this is not the case with the constituent specific objectives.
We can prioritize the general objectives based upon the scores in table 22 and compare this to the rankings obtained by the paired comparison. This has been done in table 23.
The table shows a fairly large degree of similarity between the two ways of ranking the general objectives for the OuN. The degree of difference increases by HVE and is greatest by UE. It is primarily objective *F* 'to clearly describe the experiment' and *C* 'to design experiments to test (simple) hypotheses', which yield the greatest discrepancies. For objective *F* we have already discussed the role which interpretation of the verb 'to describe' may have played in the paired comparison. This objective scored lower on the paired comparison than on the average *Z*-score for all three groups.
We are sorry to admit that we do not have an explanation for the differences for objective *C*.

Table 23
Rough sequence of general learning objectives determined on the basis of average *Z*-scores for the specific learning objectives and the paired comparison
1 = most important; 6 = least important

type of institute	*order based on:*	*1*	*2*	*3*	*4*	*5*	*6*
OuN	Z-score	0.43	0.42	0.40	0.39	-0.21	-0.85
	spec. obj.	E	B	F	A	C	D
	paired comp.	B	E	C	A	F	D
	average score	3.58	3.42	3.08	2.83	1.42	0.50
UE	Z-score	0.36	0.12	0.07	-0.15	-0.18	-0.43
	spec. obj.	F	E	D	A	C	B
	paired comp.	C	B	E	A	D	F
	average score	3.09	2.73	2.68	2.55	2.05	1.77
HVE	Z-score	0.59	0.55	0.10	-0.49	-0.50	-1.07
	spec. obj.	D	F	E	C	A	B
	paired comp.	E	A	D	B	F	C
	average score	3.29	2.64	2.57	2.43	2.14	1.93

Finally, a remark about the difference in ranking for objective *B* 'to use knowledge and skills in unfamiliar situations' in UE. While this objective ranks rather high based upon the paired comparison, it receives the lowest rank based upon the specifications. This may be due to the fact that unfamiliar situations (generally speaking) and thus in the ranking of the general objectives *should* occur in UE. In practice, though, these situations occur sparsely in undergraduate practicals (specifically speaking). This is probably reflected in the scoring of the specific objectives.

6.2.2 *Specific learning objectives: HVE compared to UE*

To compare the various institutes we make use of *Z*-scores. Appendix 20 gives the differences between HVE and UE in order of the decreasing absolute differences in *Z*-scores ($|\Delta Z|$). In order to assess the *Z*-scores we have to determine which difference in *Z*-scores is sufficiently large to characterise a difference in the identity of the institute and at the same time which disparity in *Z*-scores is small enough to ensure that the evaluation

of a specific objective is virtually the same for both institutes. For the upper limit we have chosen for a disparity of one standard deviation; for the lower limit for a disparity of half a standard deviation.
According to this criterium, HVE differs from UE in only 13 specific objectives. For these objectives either HVE puts a great deal of emphasis on them and UE does not or vice versa. In table 24 these particular objectives are shown in order of their decreasing *ΔZ*-scores.

Table 24
Specific learning objectives in which HVE differs greatly from UE

specific learning objective	*Δ(HVE - UE)*[a]	*general objective*
-calibrate instruments	1.80	D
-confirm facts, princ. and theory from lectures/books	1.76	E
-confirm already known facts and laws	1.73	E
-follow instructions	1.36	D
-discuss results with other scientists	1.29	F
-manipulate apparati	1.25	D
-keep a day-to-day lab diary	1.14	D
-design an experiment to verify a theory/hypothesis	-1.51	C
-recognize and define scientific problems	-1.48	B
-derive testable hypotheses from theories	-1.38	A
-construct models based on experimental findings	-1.36	B
-construct models which fit experimental evidence	-1.25	B

[a] $\Delta Z \geq +1$ = this learning objective is considered much more important by HVE than by UE
$\Delta Z \leq -1$ = this learning objective is considered much less important by HVE than by UE

The objectives which HVE considers to be much more important than UE relate especially to matters as practical laboratory skills or the confirmation of established facts and theories. The designing of an experiment to test a theory or the construction of models which fit experimental evidence are the type of objectives which UE values as important. One objective seems to stand out in the objectives considered more important by HVE than by UE namely the objective 'to discuss results with other scientists'. This is understandable however in view of the fact that many HVE graduates cooperate with researchers and discuss the results obtained with them. This concurs with the Vocational Education Act as discussed in paragraph 1.1. In the explanatory memorandum, the lawmakers explicitly make reference to "high standards with regard to independence, creative thinking and acting, and social skills". In the climate of 'higher education land' where UE tends to, unjustly, look down on HVE it is not strange that HVE places such an emphasis on this objective. In this way it can try to achieve equality with UE. If discussion is understood as a discussion among 'equals' on scientific symposia and congresses, it is understandable that UE circles consider this a non-objective for undergraduate practicals.
A remarkable outcome of this research is that HVE and UE show identical scores with regard to a great number of objectives for practicals.
Appendix 20 lists 38 specific learning objectives with a $|\Delta Z| \leq 0.5$. It would also be possible to draw this conclusion by comparing tables 9 and 13 in which the *indispensable* objectives for UE and HVE respectively have been classified according to the three stages

of the execution of an experiment: 'prior to the experiment', 'during the experiment' and 'after the experiment'.
The learning objectives in the stages 'prior to experiment' and 'after the experiment' appeared to coincide almost completely, except for the two objectives dealing with the evaluation of the experimental results with regard to the hypothesis. These objectives occur in UE but not in HVE. For HVE the objectives found in 'during the experiment' contain an additional five objectives besides those of UE. It is obvious that HVE considers *'real'* practical skills to be more important than UE.

6.2.3 *Specific learning objectives: OuN compared to UE and HVE*

Apart form comparing HVE with UE, we can also compare the OuN with both UE and HVE and indicate the various discrepancies. In appendix 21 and 22 the differences between OuN and HVE and between OuN and UE are given in order of decreasing absolute difference in Z-scores ($|\Delta Z|$). Again we will draw a line at $|\Delta Z| = 1$ and $|\Delta Z| = 0.5$. With the help of these limits the specific learning objectives can be classified in three groups as seen in table 25 where the number of objectives in each group is given in a comparison of the different institutes.

Table 25
The number of specific learning objectives classified according to the size of $|\Delta Z|$ in a comparison of HVE and UE, OuN and HVE and OuN and UE

comparison of	$\lvert\Delta Z\rvert \geq 1$	$0.5 < \lvert\Delta Z\rvert < 1$	$\lvert\Delta Z\rvert \leq 0.5$	
HVE and UE	12	14	38	(appendix 20)
OuN and HVE	24	14	26	(appendix 21)
OuN and UE	21	20	23	(appendix 22)

A number of noteworthy results stands out in this table:
- The number of specific learning objectives on which HVE and UE vary a great deal, is not very large (12); the number of objectives where they practically agree is considerably larger (38).
- The number of learning objectives showing considerable differences between the OuN and UE or HVE is almost equal (although the type of objective concerned *may* vary a great deal) and this particular number (21 and 24 respectively) is approximately twice as high as the number of differences between HVE and UE (12).
- The number of learning objectives on which the OuN and HVE on the one hand and the OuN and UE on the other hand hold the same views is approximately the same (26 and 23 respectively).

From the above mentioned outcomes one might again conclude that as far as practicals are concerned the OuN differs much more from HVE and UE than HVE and UE differ from one another! This conclusion is more or less in accordance with the specific character of the OuN. The component 'practicals' does not take the same place in the OuN as in HVE or UE. OuN education, for one thing, is basically education at a distance and for this reason practicals, which are imperative in time and place, have to be kept to a minimum. Another thing is that the type of education offered by the OuN is more inter- or multidisciplinary than education in the regular HVE and UE institutes. This requires a different attitude with regard to practicals. At the OuN, the ability to solve difficult scientific problems, to draw conclusions from experimental data and to evaluate these data with regard to the theory is much more important than standing behind the laboratory bench and manipulating apparati.

The specific learning objectives with considerable differences in Z-scores ($|\Delta Z| > 1$) can be viewed in yet another way. We have seen (table 25) that the OuN varies greatly from HVE with regard to 24 specific objectives. We can check how many of these objectives also occur in the list of 21 objectives the OuN differs strongly from UE. This proves to be the case with 14 of them. These 14 objectives should be considered as the objectives which provide specific information about the OuN: objectives which clearly distinguish the OuN from UE and HVE. These may be objectives which the OuN considers much more important than HVE and UE ($\Delta Z \geq 1$) or objectives which OuN values as much less important than HVE or UE ($\Delta Z \leq -1$). It does not necessarily mean that UE or HVE does not value these objectives as important, but merely that the OuN values them as either *much more important* or *much less important* (see table 26).

Table 26
Specific learning objectives with a large difference between the OuN and both HVE and UE

specific learning objective	ΔZ[a] *(OuN-HVE)*	ΔZ *(OuN-UE)*	*general objective*
-derive testable hypotheses from theories	2.72	1.34	A
-recognize and define scientific problems	2.67	1.19	B
-incorporate unexpected experimental results in a new model	2.43	2.14	E
-solve difficult scientific problems	1.96	1.37	A
-derive and evaluate relationships	1.86	1.46	A
-calibrate instruments	-3.54	-1.74	D
-manipulate apparati	-2.71	-1.46	D
-put basic laboratory techniques to use	-2.40	-1.47	D
-collect experimental data	-2.25	-1.72	D
-handle modern equipment	-2.14	-1.66	D
-set up lab equipment quickly and correctly	-1.95	-1.73	D
-carry out accurate measurements	-1.76	-1.70	D
-use practical (as opposed to theoretical) lab skills	-1.69	-1.86	D
-conduct experiments safely	-1.09	-1.47	D

[a] $\Delta Z \geq +1$ = this learning objective is considered much more important by the OuN than by HVE or UE; $\Delta Z \leq -1$ = this learning objective is considered much less important by the OuN than by HVE or UE

Although we have placed the limit at ΔZ plus or minus 1, almost all specific learning objectives with regard to which distinctive differences between the OuN and both HVE and UE can be perceived, appear to have a $|\Delta Z| > 1.50$. The differences between the OuN and HVE, however, are almost always bigger (or in case of $\Delta Z < -1$ smaller) than the differences between the OuN and UE.
The OuN deviates more from HVE than from UE, which was to be expected. The learning objectives of the list with negative ΔZ values all relate to practical manual skills '*during*' the actual realization of the experiment. All of them are specifications of general objective *D* 'to use laboratory skills in performing (simple) experiments'. Tables 9 and 13 show that UE and especially HVE value these practical laboratory skills as *indispensable* objectives, but for an OuN graduate in science they are *not really necessary* (Meester et al., 1989).

Some of the learning objectives with a $\Delta Z \geq +1$ are also shown in table 24, which represents objectives distinguishing HVE from UE. The fact that they are also shown in table 26, indicates that the OuN values these objectives even more highly (namely $\Delta Z \geq +1$) than UE and UE again more than HVE.

We can also look at the differences between the OuN on the one hand and the monodisciplines biology, chemistry and physics on the other hand.
Appendices 23, 24 and 25 give the differences between the OuN and these disciplines in order of decreasing absolute difference in Z-scores. Table 27, analogous to table 25 gives the numbers of specific objectives per group of $|\Delta Z|$ scores.

Table 27
The number of specific learning objectives classified according to the size of $|\Delta Z|$ in a comparison of the OuN with biology, chemistry and physics respectively

comparison of	$\lvert\Delta Z\rvert \geq 1$	$0.5 < \lvert\Delta Z\rvert < 1$	$\lvert\Delta Z\rvert \leq 0.5$	
OuN and biology	13	27	24	(appendix 23)
OuN and chemistry	23	22	19	(appendix 24)
OuN and physics	22	18	24	(appendix 25)

It is rather striking that biology deviates the least from the OuN. With regard to 13 objectives there are distinct dissimilarities with the OuN while 24 objectives show only minimal differences. The differences between the OuN and chemistry and physics are considerably larger, which was also the case for the general learning objectives. This is not all too strange considering the fact that the diploma programme Environmental Sciences at the OuN is rather biologically-oriented, although *'real'* chemistry, physics and geology are being taught as well.
If we compare the OuN with the monodisciplinary UE institutes on the one hand and the multidisciplinary institutes (only three in number) on the other hand it is noticeable that the OuN and the latter institutes have similar views on many objectives.

6.3 *End-terms*

Kirschner and Meester (1988) distinguish two general end-terms for practicals, namely:
I to obtain good (scientific) attitudes
II to understand the scientific method.
Each of these general end-terms has a great number of specifications. In an earlier report on the learning objectives for practicals at the Open university of the Netherlands (Meester et al., 1989) we came to the conclusion that the majority of these specifications (24 of the 38) are considered *important* or *indispensable* for the type of education provided within this institute. This is not surprising, however, if we consider that we are dealing with end-terms for a study in the Natural Sciences. The specific end-terms relating to higher academic skills scored the highest; at the bottom of the list we saw a number of end-terms with a rather 'romantic' or 'idealistic' view on undergraduate practicals.
In this paragraph we compare the results of the various types of institutes offering higher education with each other. In this comparison we will make use of the lists classifying the differences between the institutes in order of decreasing difference in Z-score (appendices 26, 27 and 28).

6.3.1 *End-terms: HVE compared to UE*

When applying, as we did in paragraph 6.2, the criterion that a $|\Delta Z| \geq 1$ indicates an essential difference between the institutes to be compared, HVE differs considerably from UE with regard to six end-terms (see table 28).
These differences confirm the picture outlined in paragraph 6.2.2. HVE is especially concerned with mastering the actual techniques of experimenting. Similarly, other end-terms related to the above are apt to score higher in HVE than in UE. UE, on the contrary, sets great store by a scientific approach to phenomena, by the ability to discover the limitations of theories and models, the formulating of a problem that can be researched and the designing of new experiments. With regard to a large number of end-terms however, the views held within these institutions apparently differ only to a slight degree: 21 of the end-terms have a ΔZ-score ≤ 0.5 (see table 29).

Table 28
End-terms showing considerable differences between HVE and UE

specific end-term	*ΔZ (HVE-UE)*[a]
-be self-confident and independent	2.19
-use motor skills inherent to professionals	1.45
-discover limitations of a theory/model	-2.56
-formulate a problem that can be researched	-1.85
-approach observed phenomena from a scientific point of view	-1.39
-design new experiments in their own fields	-1.10

[a] $\Delta Z \geq +1$ = this learning objective is considered much more important by HVE than by UE
$\Delta Z \leq -1$ = this learning objective is considered much less important by HVE than by UE

6.3.2 *End-terms: OuN compared to UE and HVE*

A division of the specific end-terms into three groups based on the $|\Delta Z|$ score generates the following picture (as represented in table 29) when comparing the OuN, UE and HVE (see also appendices 27 and 28).

Table 29
The number of specific end-terms classified according to the size of $|\Delta Z|$ in a comparison of the OuN, HVE and UE

comparison of	*$\lvert\Delta Z\rvert \geq 1$*	*$0.5 < \lvert\Delta Z\rvert < 1$*	*$\lvert\Delta Z\rvert \leq 0.5$*	
HVE and UE	6	11	21	(appendix 26)
OuN and HVE	11	9	18	(appendix 27)
OuN and UE	6	11	21	(appendix 28)

The number of end-terms showing considerable differences between the OuN and HVE (11) is approximately twice as high as those in other comparisons (6). This not surprising, however, if we consider that the OuN differs from HVE with regard to two factors: OuN provides (1) academic education and (2) distance education. We will now investigate the nature of these differences between the OuN and HVE on the one hand and the OuN and UE on the other (see tables 30 and 31).

Table 30
End-terms showing substantial differences between the OuN and HVE

specific end-term	ΔZ (OuN-HVE)[a]
-approach observed phenomena from a scientific point of view	2.29
-discover limitations of a theory/model	2.21
-formulate a problem that can be researched	2.19
-build a framework for facts, principles and theory from lectures/books	1.05
-solve problems in a critical academic way	1.03
-design new experiments in their own fields	1.02
-do experiments	-2.93
-work in research and development labs	-2.25
-use motor skills inherent to professionals	-2.11
-plan ahead	-1.30
-be interested in the subject area	-1.13

[a] $\Delta Z \geq +1$ = this learning objective is considered much more important by the OuN than by HVE
$\Delta Z \leq -1$ = this learning objective is considered much less important by the OuN than by HVE

Table 31
End-terms showing considerable differences between the OuN and UE

specific end-term	ΔZ (OuN-UE)[a]
-be self-confident and independent	1.52
-build a framework for facts princ. and theory from lectures/books	1.49
-survey literature relevant to some problem	1.12
-do experiments	-2.19
-work in research and development labs	1.53
-use the lab as an instrument for discovery	-1.31

[a] $\Delta Z \geq +1$ = this learning objective is considered much more important by the OuN than by UE
$\Delta Z \leq -1$ = this learning objective is considered much less important by the OuN than by UE

If we now compare the tables 28, 30 and 31, the most striking feature is the fact that five of the six end-terms showing differences between HVE and UE also turn up in the comparison between HVE and the OuN. Apparently we are dealing here with end-terms that discriminate between scientific and higher vocational education.
Furthermore, three end-terms appear to show differences between the OuN and both HVE and UE. Two of those ('to do experiments' and 'to work in research and development labs') relate to the ability to carry out experiments and research. The Open university of the Netherlands has to a large extent abandoned this type of activity when programming its natural science distance education. The third end-term 'to build a framework for facts, principles and theory from lectures/books' indicates that within the OuN the emphasis is on integration of (theoretical) knowledge from various sources. Another striking feature is the fact that UE considers research in literature ('to survey literature relevant to some problem') much less important than the OuN. There is one end-term which both HVE and

OuN consider much more important than UE: 'to be self-confident and independent'. A possible reason for this is that UE students, by virtue of their admission to the university are already fairly self-confident and independent. HVE and OuN students must accrue these qualities through their studies. The teachers at these institutions are well aware of this and as such place more value on such end-terms (see the specific learning objective 'to discuss results with other scientists' in paragraph 6.2.2).

Finally, the OuN can be compared to the different UE-monodisciplines. The picture which constantly came forward of the OuN being closer to biology than to the other two disciplines is not borne out here. The differences between the OuN and biology are larger than between the OuN and the other two disciplines (see table 32).

Table 32
The number of specific end-terms classified according to the size of $|\Delta Z|$ in a comparison of OuN with biology, chemistry and physics

comparison of	$\lvert\Delta Z\rvert \geq 1$	$0.5 < \lvert\Delta Z\rvert < 1$	$\lvert\Delta Z\rvert \leq 0.5$
OuN and biology	14	10	14
OuN and chemistry	7	13	18
OuN and physics	11	9	18

7 Conclusions

In light of the results presented in this report we can make a number of conclusions with respect to learning objectives and end-terms for undergraduate practicals, and for the differences and similarities between the OuN, HVE and UE.
HVE and UE approach practicals in the Natural Sciences in a monodisciplinary way. This can be seen on various aspects of this report. One example of this is the coefficient of concordance (Kendall's *W*; see table 4). The degree of concordance across the sample population is very small (especially when compared to the OuN). This increases remarkably when the population is divided into the separate disciplines, with chemistry reaching significance.
This monodisciplinary thinking is also reflected in the difference in scoring of the highest and lowest general learning objectives for the different subsamples. In HVE and UE, these differences are 1.36 and 1.32 respectively. At the OuN this difference was 3.08!
As was the case with Kendall's *W*, the difference between highest and lowest general objective also increases when we study the separate disciplines. The differences for physics, biology, and chemistry are 2.33, 2.40, and 2.75 respectively. It is evident that the different disciplines diverge as to there perception of the importance of the general learning objectives.
In comparing HVE with UE, the following two differences are noteworthy:

- UE considers the designing of (simple) experiments to test hypotheses to be very important. It ranks number 1 in UE. HVE, on the other hand, ranks this general objective in the last place. The difference between these two types of institutes, as stated in the law, namely "independent scientific work" (UE) versus "to solve concrete problems" (HVE) is evident here.
- The opposite is true with respect to the use of laboratory skills in carrying out (simple) experiments. This is also to be expected in light of what is stated in the law.

In analyzing the reactions of the respondents for the general learning objectives, the specific learning objectives and the end-terms we note the following differences between the OuN and the (separate disciplines) of UE and HVE:

- The difference between the OuN and HVE is larger than the difference between the OuN and UE. This is to be expected considering the OuN has no vocational programme in the Natural Sciences.
- The difference between the OuN and UE is larger than the difference between HVE and UE. This difference is noteworthy, but explainable. Although the OuN and UE are both academic (as opposed to vocational) institutions, this similarity is not as strong as the differences between them. UE is monodisciplinary; the OuN is not. UE trains its students to *do* research; the OuN trains its students to apply the research of others.
- The OuN emphasizes, unlike HVE, critical, academic end-terms. HVE emphasizes, as expected, motor and laboratory skills. This tendency is also evident, but to a lesser degree, in a comparison of the OuN with UE.
- The differences between the disciplines physics, chemistry, and biology are gradual. For physics it is important to work with (modern) apparati, while for chemistry and, to a greater extent, biology it is important to derive and test hypotheses. Characteristic of this is the importance attached to being able 'to solve difficult scientific problems' and 'to solve problems in a multisolution situation' by biology and chemistry but not by physics. It appears that the attainment of higher academic skills is less important in physics than in the other two disciplines.
- Except for the specific end-terms the OuN differs least from biology and most from physics. This is to be expected on the basis of the programme (Environmental Sciences) offered.
- HVE and UE both value the 'use of laboratory skills in performing (simple) experiments' (*D*) more highly than the OuN does. This was to be expected.
- The differences in ratings between coordinators and non-coordinators was almost nihil. A comparison between monodisciplinary and multi- or interdisciplinary institutions is not possible because of the small number of respondents from multi- or interdisciplinary institutes.

In conclusion:
The explanatory memorandum of the Higher Education and Scientific Research Act makes quite clear that the different types of education (academic vs. vocational) need keep their own identity. These differences are very evident in this research.

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Appendix 1 Order of priority of specific learning objectives from research within the OuN

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
9	E	Interpret reliability and meaning of results	1.25	1.64	0.45
16	E	Assess relevance of exp. data with regard to hypothesis	1.5	1.24	0.52
34	E	Apply elementary notions of statistics	1.5	1.24	0.67
23	A	Derive testable hypotheses from theories	1.67	0.98	0.49
71	F	Describe central aspects of an experiment	1.67	0.98	0.49
97	E	Relate exp. outcomes to a particular theory	1.67	0.98	0.49
102	E	Evaluate diff. expected & actual results	1.67	0.98	0.49
21	A	Decompose large to smaller problems	1.67	0.98	0.65
91	A	Understand what is to be measured in an exp.	1.67	0.98	0.65
1	E	Make order-of-magnitude calculations and estimates	1.75	0.85	0.75
84	A	Understand the purpose of an experiment	1.75	0.85	0.87
64	C	Recogn. hazards so as to take safety precautions	1.83	0.73	0.39
47	E	Evaluate exp. outcome with respect to a hypothesis	1.83	0.73	0.58
75	B	Apply known principles to new situations	1.83	0.73	0.58
87	E	Analyze exp. data to draw conclusions	1.83	0.73	0.58
94	B	React adequately to unforeseen results	1.83	0.73	0.72
5	D	Observe phenomena in a qualitative way	1.83	0.73	0.83
17	F	Present essentials of an exp. in written form	1.83	0.73	0.94
22	C	Design subsequent exp. involving phenomena	1.92	0.58	0.79
43	E	Incorporate unexpected exp. results in new model	1.92	0.58	0.79
25	F	Communicate exp. findings in written form	1.92	0.58	0.9
44	D	Be flexible in modifying exp.	1.92	0.58	0.9
54	A	Derive & evaluate relationships	1.92	0.58	0.9
41	B	Recognize & define scientific problems	2	0.46	0.43
26	E	Use obtained data to make estimates in new situations	2	0.46	0.6
33	A	Use exp. data to solve specific problems	2	0.46	0.6
63	A	Solve problems in a multi-solution situation	2	0.46	0.6
77	C	Properly plan an experiment	2	0.46	0.6
31	C	Design an exp. to verify a theory/hypothesis	2	0.46	0.74
10	E	Estimate outcome of exp. meas. within given precision	2	0.46	0.95
35	B	Apply current knowledge in solving new problems	2	0.46	1.13
56	E	Evaluate contribution direct to derived errors	2.08	0.33	0.51
55	F	Summarize an exp. based on results	2.08	0.33	0.67
86	C	Understand scope & limits of exp. techniques used	2.08	0.33	1
42	F	Communicate exp. findings in oral form	2.08	0.33	1.08
68	D	Handle waste safely	2.17	0.19	0.94
45	8	Construct models based on exp. findings	2.17	0.19	1.03
61	D	Observe phenomena in a quantitative way	2.17	0.19	1.03
72	F	Suggest follow-up investigations	2.25	0.07	0.75
62	D	Conduct experiments safely	2.25	0.07	0.87
19	E	Apply principles instead of rote formulae	2.33	-0.06	0.78
53	D	Keep a day-to-day lab diary	2.33	-0.06	1.23
38	B	Construct models which fit exp. evidence	2.33	-0.06	1.5
98	A	Understand measurement of diff. phenomena	2.42	-0.2	1.08
83	F	Discuss results with other scientists	2.42	-0.2	1.24
52	E	Process experimental data	2.5	-0.33	1.09
95	C	Design relevant observation techniques	2.5	-0.33	1.09
101	D	Understand lab instructions	2.58	-0.45	1.24
29	A	Solve difficult scientific problems	2.67	-0.59	1.07
46	A	Identify variables & determine emp. relations	2.67	-0.59	1.07
28	D	Carry out accurate measurements	2.75	-0.72	1.14
80	D	Collect experimental data	2.83	-0.85	1.11
4	D	Use practical (as opposed to theoretical) lab skills	2.92	-0.99	1.08
100	E	Confirm facts, princ. & theory from lect./books	3	-1.11	1.04
12	D	Put basic lab. techniques to use	3.08	-1.24	1.31
88	C	Translate conc. def. into set of meas. procedures	3.08	-1.24	1.44
24	D	Follow instructions	3.17	-1.38	1.27
92	D	Know & apply altern. meas. techniques	3.25	-1.51	1.22
65	E	Confirm already known facts and laws	3.42	-1.77	0.9
18	D	Manipulate apparati	3.5	-1.9	1.24
85	D	Handle modern equipment	3.58	-2.03	1.08
89	D	Set up lab equipment quickly & correctly	3.67	-2.17	1.07
32	C	Develop measurement techniques	4	-2.69	1.13
20	D	Calibrate instruments	4.17	-2.95	0.72

Appendix 2 Order of priority of end-terms from research within the OuN

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
03	II	Solve problems in a critical, academic way	1.17	2.16	0.39
08	II	Approach observed phenomena from a scient. point of view	1.33	1.88	0.49
14	I	Make decisions in proper course of action of prob-solving	1.5	1.59	0.52
79	I	Have a critical attitude to exp. results	1.5	1.59	0.52
90	I	Survey literature relevant to some problem	1.5	1.59	0.9
74	I	Interpret data in literature	1.75	1.15	1.14
49	I	Formulate a problem that can be researched	1.83	1.01	0.72
66	I	Approach a problem with an open mind	1.92	0.86	0.79
15	I	Form attitudes related to value & uses of exp. science	2	0.72	0.43
06	II	Deeply understand the discipline studied	2	0.72	1.04
37	I	Discover limitations of a theory/model	2	0.72	1.21
39	I	Act independently & take initiative	2.08	0.58	0.79
57	I	Apply one's insights, discoveries & conclusions	2.25	0.29	0.75
48	I	Plan ahead	2.33	0.15	0.49
27	II	Be interested in the subject area	2.33	0.15	1.15
11	I	Work in groups to solve scient. problems	2.42	-0.01	0.79
81	II	Appreciate relationship between nature & science	2.42	-0.01	1
76	II	Design new exp. in their own fields	2.42	-0.01	1.16
50	II	Experience challenge of exp. method	2.5	-0.15	0.9
58	I	Be self-confident and independent	2.5	-0.15	1
67	I	Take active part in the process of science	2.5	-0.15	1.09
70	I	Work independently of others	2.58	-0.29	1
78	II	Experience spirit & essence of scient. inquiry	2.58	-0.29	1
59	II	Build framework for facts, princ & theory from lect/books	2.58	-0.29	1.24
02	II	Use the lab as an instrument for discovery	2.67	-0.44	0.89
51	I	Appreciate the usual & unusual	2.67	-0.44	0.98
30	II	Determine limits under which a theory applies	2.67	-0.44	1.37
40	I	Concretize theoretical notions	2.75	-0.58	1.06
69	II	Do experiments	2.83	-0.72	0.94
13	II	Illustrate facts, princ. & theory of lectures/books	2.83	-0.72	1.03
99	I	Use mental skills inherent to professionals	2.83	-0.72	1.03
36	II	Intuitively understand scientific phenomena	2.92	-0.88	0.9
82	I	Tackle a problem without help of others	2.92	-0.88	1.08
93	II	Experience kinship with the scientist	3.25	-1.45	0.97
60	II	Experience past and present scientists' joy	3.25	-1.45	1.06
07	I	Use motor skills inherent to professionals	3.33	-1.59	0.98
73	II	Experience joys & sorrows of experimenting	3.33	-1.59	0.98
96	II	Work in research & development labs	3.5	-1.88	1.17

Appendix 2 Inventory of specific learning objectives, LDSI-7A

Appendix 3 A paired comparison of general objectives, LDSI-2

LDSI-2

Name:...............

A practical is defined as those activities relating to experimentation beginning with the conception of a question or the observation of a phenomenon through the reporting of the results in written or oral form. Examples of experimentation are: demonstrations, 'wet' labs, pen and paper experiments, simulations, etc.

This booklet contains 28 pairs of general learning objectives for practicals. Please choose the objective by each pair which you consider the most important of the two. You can do this by placing a cross (x) in the circle preceding the relevant objective. Please do not look back to or change previous choices! Thank You.

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use knowledge and skills in unfamiliar situations
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 solve problems

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 design (simple) experiments to test hypotheses
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 interpret experimental data
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 remember the central idea of an experiment over a significantly long period of time

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 solve problems

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 formulate hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 interpret experimental data
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 design (simple) experiments to test hypotheses
0 clearly describe an experiment

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 formulate hypotheses
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 interpret experimental data
0 remember the central idea of an experiment over a significantly long period of time

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 remember the central idea of an experiment over a significantly long period of time
0 solve problems

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 interpret experimental data

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 design (simple) experiments to test hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 use laboratory skills in performing (simple) experiments

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use knowledge and skills in unfamiliar situations
0 remember the central idea of an experiment over a significantly long period of time

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use knowledge and skills in unfamiliar situations
0 formulate hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 use laboratory skills in performing (simple) experiments
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 solve problems
0 use knowledge and skills in unfamiliar situations

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 clearly describe an experiment
0 formulate hypotheses

After completing an undergraduate study in the Natural Sciences, a student should be able to:

0 design (simple) experiments to test hypotheses
0 use laboratory skills in performing (simple) experiments

Appendix 5 List of general objectives and end-terms from research with the corresponding specific learning objectives and end-terms.

This classification is based upon the classification of specific learning objectives and end-terms by Meester and Kirschner (1988). The number of general learning objectives has been reduced from eight to six.
Several specific learning objectives have been reformulated; four specific learning objectives have become end-terms, and four end-terms have become specific learning objectives.
N.B.: the numbers preceding the specific learning objectives and end-terms correspond with the item number from the inventory (appendix 4).

Specific learning objectives

A. *To solve problems*

21 decompose large problems into a number of smaller problems
23 derive testable hypotheses from theories
63 solve problems in which there is more than one usable solution strategy
54 derive and evaluate relationships between observed scientific phenomena
33 use experimental data to solve specific problems
29 solve difficult scientific problems
84 understand the purpose of an experiment
91 understand what is to be measured during an experiment
98 understand how different phenomena are measured during an experiment
46 identify the variables that adequately describe some system's state and empirically determine the way they are related

B. *To use knowledge and skills in unfamiliar situations*

35 apply what is already known to solve new problems
75 apply known principles to new situations
41 recognize and define scientific problems
45 construct models based on experimental findings
38 construct models which fit experimental evidence
94 react adequately when confronted with unforeseen results

C. *To design (simple) experiments to test hypotheses*

31 design an experiment to test a theory or hypothesis
77 properly plan an experiment
95 design observation techniques relevant to the task at hand
32 develop measurement techniques
22 design subsequent experiments involving the phenomena being studied
64 recognize hazards so as to take appropriate safety precautions
86 understand the scope and limiting conditions of the experimental techniques used
88 translate a conceptual definition of a quantity into a set of measurement procedures

D. To use laboratory skills in performing (simple) experiments

24 follow instructions
101 understand laboratory instructions
4 use practical (as opposed to theoretical) laboratory skills
89 set up laboratory equipment quickly and correctly
18 manipulate apparati
62 conduct experiments safely
92 apply alternative measuring techniques for improving reliability and precision of data gained
12 put basic laboratory techniques (such as titration, microscopy or physical measurement) to use
85 handle modern equipment
20 calibrate instruments
28 carry out accurate measurements
5 observe phenomena in a qualitative way
61 observe phenomena in a quantitative way
44 be flexible with respect to modifying experiments in light of results obtained in prior experimentation
68 handle waste safely from an environmental point of view
80 collect experimental data
53 keep a day-to-day laboratory diary in such a way that a third person can repeat the experiments

E. To interpret experimental data

52 process experimental data
87 analyse experimental data in order to draw conclusions from them
19 apply principles rather than rote use of computational formulae in the theoretical analysis of the lab experiment
34 apply elementary notions of statistics (e.g. random errors, systema tic errors, mean values, uncertainty and confidence limits) in evaluating experimental data
56 evaluate how errors in direct measurements may contribute to errors in a derived measure
16 assess the relevance of experimental data with regard to a hypothe sis being studied
10 estimate the outcome of experimental measurements within a given precision prior to actual experimentation
47 evaluate the outcome of an experiment with regard to the hypothesis being tested
1 make order-of-magnitude calculations and estimates
43 incorporate unexpected experimental results in a new model
102 evaluate why expected (theoretical) results differ from actual experimental findings
26 use data already obtained to make estimates regarding not yet tested situations
9 interpret the reliability and meaning of results gained through experimentation (either their own or those of others)
97 relate the outcomes of an experiment to a particular theory
100 confirm facts, principles and theories discussed in lectures or books
65 confirm already known facts and laws

F. To clearly describe the experiment

17 present the essentials of an experiment in written form
55 summarize the important aspects of an experiment based on collected data
71 describe the central aspects of an experiment (i.e. its goals, underlying theory and basic methods)
25 communicate experimental findings in written form
42 communicate experimental findings in oral form
72 suggest follow-up investigations once the results of a scientific investigation are known
83 discuss results of scientific investigations with other scientists

End-terms

I. To obtain good scientific attitudes

49 formulate a problem so that it can be researched
90 survey the literature relevant to some problem at hand
14 make decisions as to the proper course of action in solving problems
79 have a critical attitude towards experimentally gained results
58 be self-confident and independent
39 act independently and take initiative
82 tackle a problem without the help of others
48 plan ahead
40 concretize (illustrate) theoretical notions
15 form attitudes relating to the value and uses of experimental science (physics, biology and chemistry)
57 apply one's own insights, discoveries and conclusions in explaining observed phenomena
37 discover the limitations of a theory or model
66 approach a problem with an open mind
11 work in groups to solve scientific problems
70 work independently of others
67 actively take part in the process of science
99 use mental skills inherent to professionals in the natural sciences
74 interpret data in the literature
7 use motor skills inherent to professionals in the natural sciences
51 appreciate the usual as well as the unusual within the natural sciences

II. To understand the scientific method

81 appreciate the relationship between nature and science
36 intuitively understand scientific phenomena
30 determine the limits under which a theory applies
69 do experiments
13 illustrate facts, principles and theories discussed in lectures or books
59 build a framework for facts, principles and theories encountered in lectures and books
2 use the laboratory as an instrument for discovery
96 work in research and developments laboratories
8 approach observed phenomena from a scientific point of view
50 experience the intellectual challenge of using the experimental method
73 experience the joys and sorrows of experimenting
93 experience a kinship with the scientist
60 experience the joy experienced by scientists past and present
6 deeply understand the discipline studied (as opposed to being able to simply work by the book)
78 experience the spirit of scientific inquiry and the essence of scientific thinking
27 be interested in the subject area being studied.
76 design new experiments in their own field of research
3 solve problems in a critical, academic way

Appendix 6 x, Z and s.d. of specific learning objectives for UE institutes

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
62	D	Conduct experiments safely	1.32	1.54	0.48
84	A	Understand the purpose of an experiment	1.32	1.54	0.48
9	E	Interpret reliability and meaning of results	1.36	1.46	0.49
17	F	Present essentials of an exp. in written form	1.36	1.46	0.49
91	A	Understand what is to be measured in an exp.	1.36	1.46	0.58
25	F	Communicate exp. findings in written form	1.41	1.35	0.5
77	C	Properly plan an experiment	1.5	1.17	0.51
16	E	Assess relevance of exp. data with regard to hypothesis	1.5	1.17	0.67
64	C	Recogn. hazards so as to take safety precautions	1.5	1.17	0.8
87	E	Analyze exp. data to draw conclusions	1.55	1.06	0.51
47	E	Evaluate exp. outcome with respect to a hypothesis	1.59	0.98	0.5
28	D	Carry out accurate measurements	1.59	0.98	0.59
56	E	Evaluate contribution direct to derived errors	1.62	0.92	0.74
61	D	Observe phenomena in a quantitative way	1.64	0.87	0.49
4	D	Use practical (as opposed to theoretical) lab skills	1.64	0.87	0.66
80	D	Collect experimental data	1.64	0.87	0.66
102	E	Evaluate diff. expected & actual results	1.68	0.79	0.57
52	E	Process experimental data	1.73	0.69	0.55
71	F	Describe central aspects of an experiment	1.73	0.69	0.55
98	A	Understand measurement of diff. phenomena	1.73	0.69	0.63
34	E	Apply elementary notions of statistics	1.73	0.69	0.77
55	F	Summarize an exp. based on results	1.76	0.62	0.7
1	E	Make order-of-magnitude calculations and estimates	1.77	0.6	0.61
101	D	Understand lab instructions	1.82	0.5	0.91
68	D	Handle waste safely	1.82	0.5	1.05
86	C	Understand scope & limits of exp. techniques used	1.95	0.23	0.58
33	A	Use exp. data to solve specific problems	1.95	0.23	0.74
31	C	Design an exp. to verify a theory/hypothesis	1.95	0.23	0.84
12	D	Put basic lab. techniques to use	1.95	0.23	0.95
97	E	Relate exp. outcomes to a particular theory	2	0.12	0.53
5	D	Observe phenomena in a qualitative way	2	0.12	0.62
10	E	Estimate outcome of exp. meas. within given precision	2	0.12	0.62
19	E	Apply principles instead of rote formulae	2	0.12	0.62
35	B	Apply current knowledge in solving new problems	2.05	0.02	0.95
21	A	Decompose large to smaller problems	2.09	-0.06	0.75
22	C	Design subsequent exp. involving phenomena	2.09	-0.06	0.75
75	B	Apply known principles to new situations	2.09	-0.06	0.75
26	E	Use obtained data to make estimates in new situations	2.14	-0.17	0.77
72	F	Suggest follow-up investigations	2.14	-0.17	0.77
42	F	Communicate exp. findings in oral form	2.14	-0.17	0.94
85	D	Handle modern equipment	2.23	-0.36	0.87
94	B	React adequately to unforeseen results	2.23	-0.36	0.87
23	A	Derive testable hypotheses from theories	2.23	-0.36	1.02
89	D	Set up lab equipment quickly & correctly	2.27	-0.44	0.7
18	D	Manipulate apparati	2.27	-0.44	0.98
53	D	Keep a day-to-day lab diary	2.27	-0.44	1.2
44	D	Be flexible in modifying exp.	2.32	-0.54	1.09
45	B	Construct models based on exp. findings	2.41	-0.73	0.96
38	B	Construct models which fit exp. evidence	2.41	-0.73	1.05
41	B	Recognize & define scientific problems	2.41	-0.73	1.14
54	A	Derive & evaluate relationships	2.48	-0.88	0.75
88	C	Translate conc. def. into set of meas. procedures	2.5	-0.92	0.8
92	D	Know & apply altern. meas. techniques	2.5	-0.92	0.8
46	A	Identify variables & determine emp. relations	2.55	-1.02	0.96
24	D	Follow instructions	2.55	-1.02	1.06
63	A	Solve problems in a multi-solution situation	2.59	-1.11	1.05
20	D	Calibrate instruments	2.64	-1.21	1.05
95	C	Design relevant observation techniques	2.68	-1.29	0.99
83	F	Discuss results with other scientists	2.68	-1.29	1.13
43	E	Incorporate unexpected exp. results in new model	2.81	-1.56	1.08
32	C	Develop measurement techniques	3	-1.96	0.98
29	A	Solve difficult scientific problems	3	-1.96	1.38
100	E	Confirm facts, princ. & theory from lect./books	3.24	-2.46	1.09
65	E	Confirm already known facts and laws	3.33	-2.65	0.91

Appendix 7 *x*, *Z* and *s.d.* of specific learning objectives for HVE institutes

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
17	F	Present essentials of an exp. in written form	1.21	1.4	0.43
80	D	Collect experimental data	1.21	1.4	0.43
91	A	Understand what is to be measured in an exp.	1.29	1.27	0.47
9	E	Interpret reliability and meaning of results	1.36	1.16	0.5
62	D	Conduct experiments safely	1.36	1.16	0.84
101	D	Understand lab instructions	1.36	1.16	0.84
12	D	Put basic lab. techniques to use	1.36	1.16	0.84
28	D	Carry out accurate measurements	1.43	1.04	0.65
25	F	Communicate exp. findings in written form	1.5	0.93	0.52
34	E	Apply elementary notions of statistics	1.5	0.93	0.52
84	A	Understand the purpose of an experiment	1.5	0.93	0.65
64	C	Recogn. hazards so as to take safety precautions	1.5	0.93	0.85
77	C	Properly plan an experiment	1.57	0.81	0.51
86	C	Understand scope & limits of exp. techniques used	1.57	0.81	0.65
5	D	Observe phenomena in a qualitative way	1.57	0.81	0.76
18	D	Manipulate apparati	1.57	0.81	0.85
55	F	Summarize an exp. based on results	1.64	0.7	0.5
56	E	Evaluate contribution direct to derived errors	1.64	0.7	0.63
1	E	Make order-of-magnitude calculations and estimates	1.64	0.7	0.63
[illegible]	D	Use practical (as opposed to theoretical) lab skills	1.64	0.7	0.84
53	D	Keep a day-to-day lab diary	1.64	0.7	1.15
87	E	Analyze exp. data to draw conclusions	1.71	0.59	0.61
68	D	Handle waste safely	1.71	0.59	0.91
20	D	Calibrate instruments	1.71	0.59	1.14
52	E	Process experimental data	1.79	0.46	0.58
42	F	Communicate exp. findings in oral form	1.79	0.46	0.58
71	F	Describe central aspects of an experiment	1.79	0.46	0.7
102	E	Evaluate diff. expected & actual results	1.79	0.46	0.8
26	E	Use obtained data to make estimates in new situations	1.86	0.34	0.36
24	D	Follow instructions	1.86	0.34	0.66
61	D	Observe phenomena in a quantitative way	1.86	0.34	0.86
16	E	Assess relevance of exp. data with regard to hypothesis	1.93	0.23	0.47
98	A	Understand measurement of diff. phenomena	1.93	0.23	0.62
10	E	Estimate outcome of exp. meas. within given precision	2	0.12	0.55
35	B	Apply current knowledge in solving new problems	2	0.12	0.55
94	B	React adequately to unforeseen results	2	0.12	0.68
21	A	Decompose large to smaller problems	2	0.12	0.78
85	D	Handle modern equipment	2	0.12	1.11
33	A	Use exp. data to solve specific problems	2.07	0	0.27
47	E	Evaluate exp. outcome with respect to a hypothesis	2.07	0	0.47
83	F	Discuss results with other scientists	2.07	0	0.92
72	F	Suggest follow-up investigations	2.14	-0.11	0.66
44	D	Be flexible in modifying exp.	2.21	-0.22	0.7
89	D	Set up lab equipment quickly & correctly	2.21	-0.22	1.37
97	E	Relate exp. outcomes to a particular theory	2.29	-0.35	0.61
75	B	Apply known principles to new situations	2.29	-0.35	0.61
19	E	Apply principles instead of rote formulae	2.29	-0.35	0.73
92	D	Know & apply altern. meas. techniques	2.36	-0.47	0.74
63	A	Solve problems in a multi-solution situation	2.36	-0.47	0.74
100	E	Confirm facts, princ. & theory from lect./books	2.5	-0.7	0.76
22	C	Design subsequent exp. involving phenomena	2.64	-0.92	0.84
65	E	Confirm already known facts and laws	2.64	-0.92	1.28
88	C	Translate conc. def. into set of meas. procedures	2.86	-1.28	0.77
95	C	Design relevant observation techniques	2.86	-1.28	0.77
31	C	Design an exp. to verify a theory/hypothesis	2.86	-1.28	0.86
54	A	Derive & evaluate relationships	2.86	-1.28	0.86
46	A	Identify variables & determine emp. relations	3	-1.51	1.11
32	C	Develop measurement techniques	3.14	-1.74	0.95
23	A	Derive testable hypotheses from theories	3.14	-1.74	1.03
43	E	Incorporate unexpected exp. results in new model	3.21	-1.85	1.19
38	B	Construct models which fit exp. evidence	3.29	-1.98	0.91
45	B	Construct models based on exp. findings	3.36	-2.09	0.93
41	B	Recognize & define scientific problems	3.43	-2.21	0.94
29	A	Solve difficult scientific problems	3.64	-2.55	1.08

Appendix 8 *x*, *Z* and *s.d.* of specific learning objectives for UE-biology

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
16	E	Assess relevance of exp. data with regard to hypothesis	1	1.88	0
91	A	Understand what is to be measured in an exp.	1	1.88	0
77	C	Properly plan an experiment	1.2	1.45	0.45
9	E	Interpret reliability and meaning of results	1.4	1.01	0.55
12	D	Put basic lab. techniques to use	1.4	1.01	0.55
28	D	Carry out accurate measurements	1.4	1.01	0.55
31	C	Design an exp. to verify a theory/hypothesis	1.4	1.01	0.55
47	E	Evaluate exp. outcome with respect to a hypothesis	1.4	1.01	0.55
55	F	Summarize an exp. based on results	1.4	1.01	0.55
62	D	Conduct experiments safely	1.4	1.01	0.55
68	D	Handle waste safely	1.4	1.01	0.55
84	A	Understand the purpose of an experiment	1.4	1.01	0.55
4	D	Use practical (as opposed to theoretical) lab skills	1.6	0.58	0.55
17	F	Present essentials of an exp. in written form	1.6	0.58	0.55
19	E	Apply principles instead of rote formulae	1.6	0.58	0.55
23	A	Derive testable hypotheses from theories	1.6	0.58	0.55
25	F	Communicate exp. findings in written form	1.6	0.58	0.55
38	B	Construct models which fit exp. evidence	1.6	0.58	0.55
42	F	Communicate exp. findings in oral form	1.6	0.58	0.55
56	E	Evaluate contribution direct to derived errors	1.6	0.58	0.55
61	D	Observe phenomena in a quantitative way	1.6	0.58	0.55
64	C	Recogn. hazards so as to take safety precautions	1.6	0.58	0.55
71	F	Describe central aspects of an experiment	1.6	0.58	0.55
72	F	Suggest follow-up investigations	1.6	0.58	0.55
80	D	Collect experimental data	1.6	0.58	0.55
98	A	Understand measurement of diff. phenomena	1.6	0.58	0.55
102	E	Evaluate diff. expected & actual results	1.6	0.58	0.55
22	C	Design subsequent exp. involving phenomena	1.8	0.15	0.45
33	A	Use exp. data to solve specific problems	1.8	0.15	0.45
35	B	Apply current knowledge in solving new problems	1.8	0.15	0.45
44	D	Be flexible in modifying exp.	1.8	0.15	0.45
45	B	Construct models based on exp. findings	1.8	0.15	0.45
52	E	Process experimental data	1.8	0.15	0.45
75	B	Apply known principles to new situations	1.8	0.15	0.45
87	E	Analyze exp. data to draw conclusions	1.8	0.15	0.45
97	E	Relate exp. outcomes to a particular theory	1.8	0.15	0.45
101	D	Understand lab instructions	1.8	0.15	0.45
1	E	Make order-of-magnitude calculations and estimates	1.8	0.15	0.84
10	E	Estimate outcome of exp. meas. within given precision	1.8	0.15	0.84
21	A	Decompose large to smaller problems	1.8	0.15	0.84
34	E	Apply elementary notions of statistics	1.8	0.15	1.3
43	E	Incorporate unexpected exp. results in new model	2	-0.28	0
41	B	Recognize & define scientific problems	2	-0.28	0.71
86	C	Understand scope & limits of exp. techniques used	2	-0.28	0.71
88	C	Translate conc. def. into set of meas. procedures	2	-0.28	0.71
53	D	Keep a day-to-day lab diary	2	-0.28	1.22
92	D	Know & apply altern. meas. techniques	2.2	-0.71	0.45
94	B	React adequately to unforeseen results	2.2	-0.71	0.45
5	D	Observe phenomena in a qualitative way	2.2	-0.71	0.84
63	A	Solve problems in a multi-solution situation	2.2	-0.71	0.84
95	C	Design relevant observation techniques	2.2	-0.71	0.84
20	D	Calibrate instruments	2.2	-0.71	1.1
26	E	Use obtained data to make estimates in new situations	2.2	-0.71	1.1
54	A	Derive & evaluate relationships	2.2	-0.82	0.96
89	D	Set up lab equipment quickly & correctly	2.4	-1.15	0.55
29	A	Solve difficult scientific problems	2.4	-1.15	1.14
83	F	Discuss results with other scientists	2.4	-1.15	1.14
24	D	Follow instructions	2.6	-1.58	0.55
18	D	Manipulate apparati	2.6	-1.58	0.89
46	A	Identify variables & determine emp. relations	2.6	-1.58	0.89
85	D	Handle modern equipment	2.8	-2.01	1.1
32	C	Develop measurement techniques	3	-2.44	1
65	E	Confirm already known facts and laws	3	-2.44	1
100	E	Confirm facts, princ. & theory from lect./books	3.2	-2.87	1.3

Appendix 9 x, *Z* and *s.d.* of specific learning objectives for UE-chemistry

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
62	D	Conduct experiments safely	1.13	1.71	0.35
77	C	Properly plan an experiment	1.25	1.47	0.46
84	A	Understand the purpose of an experiment	1.25	1.47	0.46
87	E	Analyze exp. data to draw conclusions	1.25	1.47	0.46
9	E	Interpret reliability and meaning of results	1.38	1.22	0.52
17	F	Present essentials of an exp. in written form	1.38	1.22	0.52
25	F	Communicate exp. findings in written form	1.38	1.22	0.52
80	D	Collect experimental data	1.38	1.22	0.52
91	A	Understand what is to be measured in an exp.	1.38	1.22	0.74
64	C	Recogn. hazards so as to take safety precautions	1.38	1.22	1.06
47	E	Evaluate exp. outcome with respect to a hypothesis	1.5	0.98	0.53
68	D	Handle waste safely	1.5	0.98	0.53
61	D	Observe phenomena in a quantitative way	1.5	0.98	0.53
33	A	Use exp. data to solve specific problems	1.5	0.98	0.76
101	D	Understand lab instructions	1.5	0.98	1.07
102	E	Evaluate diff. expected & actual results	1.63	0.72	0.52
28	D	Carry out accurate measurements	1.63	0.72	0.74
52	E	Process experimental data	1.63	0.72	0.74
34	E	Apply elementary notions of statistics	1.63	0.72	0.74
16	E	Assess relevance of exp. data with regard to hypothesis	1.63	0.72	0.92
1	E	Make order-of-magnitude calculations and estimates	1.75	0.49	0.46
86	C	Understand scope & limits of exp. techniques used	1.75	0.49	0.46
12	D	Put basic lab. techniques to use	1.75	0.49	0.71
4	D	Use practical (as opposed to theoretical) lab skills	1.75	0.49	0.71
98	A	Understand measurement of diff. phenomena	1.75	0.49	0.71
56	E	Evaluate contribution direct to derived errors	1.75	0.49	1.04
85	D	Handle modern equipment	1.87	0.25	0.64
55	F	Summarize an exp. based on results	1.87	0.25	0.99
71	F	Describe central aspects of an experiment	1.88	0.23	0.64
5	D	Observe phenomena in a qualitative way	1.88	0.23	0.64
63	A	Solve problems in a multi-solution situation	1.88	0.23	0.64
97	E	Relate exp. outcomes to a particular theory	2	-0.01	0.53
19	E	Apply principles instead of rote formulae	2	-0.01	0.76
26	E	Use obtained data to make estimates in new situations	2	-0.01	0.76
18	D	Manipulate apparati	2	-0.01	0.76
31	C	Design an exp. to verify a theory/hypothesis	2	-0.01	0.93
35	B	Apply current knowledge in solving new problems	2	-0.01	0.93
10	E	Estimate outcome of exp. meas. within given precision	2.13	-0.26	0.64
21	A	Decompose large to smaller problems	2.13	-0.26	0.83
75	B	Apply known principles to new situations	2.13	-0.26	0.99
53	D	Keep a day-to-day lab diary	2.13	-0.26	1.25
94	B	React adequately to unforeseen results	2.13	-0.26	1.25
42	F	Communicate exp. findings in oral form	2.25	-0.5	0.71
22	C	Design subsequent exp. involving phenomena	2.25	-0.5	0.89
89	D	Set up lab equipment quickly & correctly	2.25	-0.5	0.89
46	A	Identify variables & determine emp. relations	2.25	-0.5	1.04
23	A	Derive testable hypotheses from theories	2.25	-0.5	1.16
44	D	Be flexible in modifying exp.	2.25	-0.5	1.16
24	D	Follow instructions	2.25	-0.5	1.49
54	A	Derive & evaluate relationships	2.38	-0.76	0.92
72	F	Suggest follow-up investigations	2.38	-0.76	1.06
92	D	Know & apply altern. meas. techniques	2.38	-0.76	1.06
38	B	Construct models which fit exp. evidence	2.38	-0.76	1.3
45	B	Construct models based on exp. findings	2.5	-0.99	1.31
88	C	Translate conc. def. into set of meas. procedures	2.63	-1.25	0.92
41	B	Recognize & define scientific problems	2.63	-1.25	1.41
32	C	Develop measurement techniques	2.75	-1.49	0.89
20	D	Calibrate instruments	2.75	-1.49	1.04
29	A	Solve difficult scientific problems	2.75	-1.49	1.67
95	C	Design relevant observation techniques	2.88	-1.74	1.25
83	F	Discuss results with other scientists	2.88	-1.74	1.25
100	E	Confirm facts, princ. & theory from lect./books	3	-1.98	1.2
43	E	Incorporate unexpected exp. results in new model	3	-1.98	1.41
65	E	Confirm already known facts and laws	3.38	-2.73	1.06

Appendix 10 $\bar{x}$, Z and s.d. of specific learning objectives for UE-physics

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
9	E	Interpret reliability and meaning of results	1.33	1.51	0.52
17	F	Present essentials of an exp. in written form	1.33	1.51	0.52
84	A	Understand the purpose of an experiment	1.33	1.51	0.52
25	F	Communicate exp. findings in written form	1.5	1.23	0.55
28	D	Carry out accurate measurements	1.5	1.23	0.55
56	E	Evaluate contribution direct to derived errors	1.5	1.23	0.55
62	D	Conduct experiments safely	1.5	1.23	0.55
91	A	Understand what is to be measured in an exp.	1.5	1.23	0.55
4	D	Use practical (as opposed to theoretical) lab skills	1.5	1.23	0.84
16	E	Assess relevance of exp. data with regard to hypothesis	1.67	0.94	0.52
34	E	Apply elementary notions of statistics	1.67	0.94	0.52
52	E	Process experimental data	1.67	0.94	0.52
61	D	Observe phenomena in a quantitative way	1.67	0.94	0.52
71	F	Describe central aspects of an experiment	1.67	0.94	0.52
87	E	Analyze exp. data to draw conclusions	1.67	0.94	0.52
102	E	Evaluate diff. expected & actual results	1.67	0.94	0.52
64	C	Recogn. hazards so as to take safety precautions	1.67	0.94	0.82
80	D	Collect experimental data	1.67	0.94	0.82
47	E	Evaluate exp. outcome with respect to a hypothesis	1.83	0.67	0.41
77	C	Properly plan an experiment	1.83	0.67	0.41
1	E	Make order-of-magnitude calculations and estimates	1.83	0.67	0.75
18	D	Manipulate apparati	1.83	0.67	0.75
85	D	Handle modern equipment	1.83	0.67	0.75
98	A	Understand measurement of diff. phenomena	1.83	0.67	0.75
5	D	Observe phenomena in a qualitative way	2	0.38	0
55	F	Summarize an exp. based on results	2	0.38	0
89	D	Set up lab equipment quickly & correctly	2	0.38	0.63
94	B	React adequately to unforeseen results	2	0.38	0.63
97	E	Relate exp. outcomes to a particular theory	2	0.38	0.63
10	E	Estimate outcome of exp. meas. within given precision	2.17	0.1	0.41
12	D	Put basic lab. techniques to use	2.17	0.1	0.41
19	E	Apply principles instead of rote formulae	2.17	0.1	0.41
72	F	Suggest follow-up investigations	2.17	0.1	0.41
86	C	Understand scope & limits of exp. techniques used	2.17	0.1	0.41
21	A	Decompose large to smaller problems	2.33	-0.17	0.52
22	C	Design subsequent exp. involving phenomena	2.33	-0.17	0.82
26	E	Use obtained data to make estimates in new situations	2.33	-0.17	0.82
31	C	Design an exp. to verify a theory/hypothesis	2.33	-0.17	0.82
53	D	Keep a day-to-day lab diary	2.33	-0.17	0.82
75	8	Apply known principles to new situations	2.33	-0.17	0.82
101	D	Understand lab instructions	2.33	-0.17	1.03
33	A	Use exp. data to solve specific problems	2.4	-0.29	0.55
54	A	Derive & evaluate relationships	2.5	-0.46	0.55
92	D	Know & apply altern. meas. techniques	2.5	-0.46	0.55
35	8	Apply current knowledge in solving new problems	2.5	-0.46	1.38
20	D	Calibrate instruments	2.67	-0.74	0.82
23	A	Derive testable hypotheses from theories	2.67	-0.74	0.82
45	B	Construct models based on exp. findings	2.67	-0.74	0.82
88	C	Translate conc. def. into set of meas. procedures	2.67	-0.74	0.82
95	C	Design relevant observation techniques	2.67	-0.74	0.82
42	F	Communicate exp. findings in oral form	2.67	-0.74	1.37
38	8	Construct models which fit exp. evidence	2.83	-1.01	0.75
41	8	Recognize & define scientific problems	2.83	-1.01	1.17
46	A	Identify variables & determine emp. relations	2.83	-1.01	1.17
83	F	Discuss results with other scientists	2.83	-1.01	1.33
44	D	Be flexible in modifying exp.	2.83	-1.01	1.47
24	D	Follow instructions	3	-1.3	0.89
32	C	Develop measurement techniques	3	-1.3	1.26
68	D	Handle waste safely	3	-1.3	1.26
43	E	Incorporate unexpected exp. results in new model	3.17	-1.59	0.98
100	E	Confirm facts, princ. & theory from lect./books	3.4	-1.97	1.14
63	A	Solve problems in a multi-solution situation	3.5	-2.14	1.05
65	E	Confirm already known facts and laws	3.6	-2.31	0.89
29	A	Solve difficult scientific problems	3.67	-2.43	1.37

Appendix 11 x, Z and $s.d.$ of specific learning objectives for UE: monodisciplinary

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
62	D	Conduct experiments safely	1.32	1.52	0.48
84	A	Understand the purpose of an experiment	1.32	1.52	0.48
91	A	Understand what is to be measured in an exp.	1.32	1.52	0.58
9	E	Interpret reliability and meaning of results	1.37	1.41	0.5
17	F	Present essentials of an exp. in written form	1.42	1.31	0.51
~7	C	Properly plan an experiment	1.42	1.31	0.51
25	F	Communicate exp. findings in written form	1.47	1.2	0.51
16	E	Assess relevance of exp. data with regard to hypothesis	1.47	1.2	0.7
87	E	Analyze exp. data to draw conclusions	1.53	1.07	0.51
28	D	Carry out accurate measurements	1.53	1.07	0.61
80	D	Collect experimental data	1.53	1.07	0.61
64	C	Recogn. hazards so as to take safety precautions	1.53	1.07	0.84
47	E	Evaluate exp. outcome with respect to a hypothesis	1.58	0.97	0.51
61	D	Observe phenomena in a quantitative way	1.58	0.97	0.51
102	E	Evaluate diff. expected & actual results	1.63	0.86	0.5
4	D	Use practical (as opposed to theoretical) lab skills	1.63	0.86	0.68
56	E	Evaluate contribution direct to derived errors	1.63	0.86	0.76
52	E	Process experimental data	1.68	0.76	0.58
34	E	Apply elementary notions of statistics	1.68	0.76	0.82
71	F	Describe central aspects of an experiment	1.74	0.63	0.56
98	A	Understand measurement of diff. phenomena	1.74	0.63	0.65
55	F	Summarize an exp. based on results	1.78	0.54	0.73
1	E	Make order-of-magnitude calculations and estimates	1.79	0.52	0.63
12	D	Put basic lab. techniques to use	1.79	0.52	0.63
33	A	Use exp. data to solve specific problems	1.83	0.44	0.71
101	D	Understand lab instructions	1.84	0.42	0.96
86	C	Understand scope & limits of exp. techniques used	1.95	0.18	0.52
97	E	Relate exp. outcomes to a particular theory	1.95	0.18	0.52
19	E	Apply principles instead of rote formulae	1.95	0.18	0.62
31	C	Design an exp. to verify a theory/hypothesis	1.95	0.18	0.85
68	D	Handle waste safely	1.95	0.18	1.08
5	D	Observe phenomena in a qualitative way	2	0.08	0.58
10	E	Estimate outcome of exp. meas. within given precision	2.05	-0.03	0.62
21	A	Decompose large to smaller problems	2.11	-0.16	0.74
18	D	Manipulate apparati	2.11	-0.16	0.81
72	F	Suggest follow-up investigations	2.11	-0.16	0.81
75	B	Apply known principles to new situations	2.11	-0.16	0.81
85	D	Handle modern equipment	2.11	-0.16	0.88
94	B	React adequately to unforeseen results	2.11	-0.16	0.88
35	B	Apply current knowledge in solving new problems	2.11	-0.16	0.99
22	C	Design subsequent exp. involving phenomena	2.16	-0.26	0.76
26	E	Use obtained data to make estimates in new situations	2.16	-0.26	0.83
53	D	Keep a day-to-day lab diary	2.16	-0.26	1.07
89	D	Set up lab equipment quickly & correctly	2.21	-0.37	0.71
23	A	Derive testable hypotheses from theories	2.21	-0.37	0.98
42	F	Communicate exp. findings in oral form	2.21	-0.37	0.98
38	B	Construct models which fit exp. evidence	2.32	-0.6	1.06
44	D	Be flexible in modifying exp.	2.32	-0.6	1.16
92	D	Know & apply altern. meas. techniques	2.37	-0.71	0.76
45	B	Construct models based on exp. findings	2.37	-0.71	1.01
54	A	Derive & evaluate relationships	2.39	-0.75	0.78
88	C	Translate conc. def. into set of meas. procedures	2.47	-0.92	0.84
63	A	Solve problems in a multi-solution situation	2.47	-0.92	1.07
46	A	Identify variables & determine emp. relations	2.53	-1.05	1.02
41	8	Recognize & define scientific problems	2.53	-1.05	1.17
20	D	Calibrate instruments	2.58	-1.16	0.96
24	D	Follow instructions	2.58	-1.16	1.12
95	C	Design relevant observation techniques	2.63	-1.26	1.01
83	F	Discuss results with other scientists	2.74	-1.49	1.19
43	E	Incorporate unexpected exp. results in new model	2.83	-1.69	1.15
32	C	Develop measurement techniques	2.89	-1.81	0.99
29	A	Solve difficult scientific problems	2.95	-1.94	1.47
100	E	Confirm facts, princ. & theory from lect./books	3.17	-2.41	1.15
65	E	Confirm already known facts and laws	3.33	-2.75	0.97

Appendix 12 x, Z and s.d. of specific learning objectives for UE: inter-/multidisciplinary

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
17	F	Present essentials of an exp. in written form	1	1.77	0
25	F	Communicate exp. findings in written form	1	1.77	0
68	D	Handle waste safely	1	1.77	0
62	D	Conduct experiments safely	1.33	1.29	0.58
84	A	Understand the purpose of an experiment	1.33	1.29	0.58
9	E	Interpret reliability and meaning of results	1.33	1.29	0.58
64	C	Recogn. hazards so as to take safety precautions	1.33	1.29	0.58
56	E	Evaluate contribution direct to derived errors	1.5	1.04	0.71
91	A	Understand what is to be measured in an exp.	1.67	0.79	0.58
16	E	Assess relevance of exp. data with regard to hypothesis	1.67	0.79	0.58
87	E	Analyze exp. data to draw conclusions	1.67	0.79	0.58
47	E	Evaluate exp. outcome with respect to a hypothesis	1.67	0.79	0.58
4	D	Use practical (as opposed to theoretical) lab skills	1.67	0.79	0.58
71	F	Describe central aspects of an experiment	1.67	0.79	0.58
98	A	Understand measurement of diff. phenomena	1.67	0.79	0.58
55	F	Summarize an exp. based on results	1.67	0.79	0.58
1	E	Make order-of-magnitude calculations and estimates	1.67	0.79	0.58
101	D	Understand lab instructions	1.67	0.79	0.58
10	E	Estimate outcome of exp. meas. within given precision	1.67	0.79	0.58
35	B	Apply current knowledge in solving new problems	1.67	0.79	0.58
22	C	Design subsequent exp. involving phenomena	1.67	0.79	0.58
42	F	Communicate exp. findings in oral form	1.67	0.79	0.58
41	B	Recognize & define scientific problems	1.67	0.79	0.58
77	C	Properly plan an experiment	2	0.31	0
28	D	Carry out accurate measurements	2	0.31	0
61	D	Observe phenomena in a quantitative way	2	0.31	0
52	E	Process experimental data	2	0.31	0
34	E	Apply elementary notions of statistics	2	0.31	0
75	B	Apply known principles to new situations	2	0.31	0
26	E	Use obtained data to make estimates in new situations	2	0.31	0
102	E	Evaluate diff. expected & actual results	2	0.31	1
86	C	Understand scope & limits of exp. techniques used	2	0.31	1
31	C	Design an exp. to verify a theory/hypothesis	2	0.31	1
5	D	Observe phenomena in a qualitative way	2	0.31	1
21	A	Decompose large to smaller problems	2	0.31	1
80	D	Collect experimental data	2.33	-0.17	0.58
97	E	Relate exp. outcomes to a particular theory	2.33	-0.17	0.58
19	E	Apply principles instead of rote formulae	2.33	-0.17	0.58
72	F	Suggest follow-up investigations	2.33	-0.17	0.58
44	D	Be flexible in modifying exp.	2.33	-0.17	0.58
24	D	Follow instructions	2.33	-0.17	0.58
83	F	Discuss results with other scientists	2.33	-0.17	0.58
23	A	Derive testable hypotheses from theories	2.33	-0.17	1.53
33	A	Use exp. data to solve specific problems	2.67	-0.67	0.58
89	D	Set up lab equipment quickly & correctly	2.67	-0.67	0.58
45	B	Construct models based on exp. findings	2.67	-0.67	0.58
88	C	Translate conc. def. into set of meas. procedures	2.67	-0.67	0.58
46	A	Identify variables & determine emp. relations	2.67	-0.67	0.58
43	E	Incorporate unexpected exp. results in new model	2.67	-0.67	0.58
85	D	Handle modern equipment	3	-1.16	0
94	B	React adequately to unforeseen results	3	-1.16	0
54	A	Derive & evaluate relationships	3	-1.16	0
38	B	Construct models which fit exp. evidence	3	-1.16	1
95	C	Design relevant observation techniques	3	-1.16	1
20	D	Calibrate instruments	3	-1.16	1.73
12	D	Put basic lab. techniques to use	3	-1.16	2
53	D	Keep a day-to-day lab diary	3	-1.16	2
92	D	Know & apply altern. meas. techniques	3.33	-1.64	0.58
63	A	Solve problems in a multi-solution situation	3.33	-1.64	0.58
29	A	Solve difficult scientific problems	3.33	-1.64	0.58
65	E	Confirm already known facts and laws	3.33	-1.64	0.58
18	D	Manipulate apparati	3.33	-1.64	1.53
32	C	Develop measurement techniques	3.67	-2.14	0.58
100	E	Confirm facts, princ. & theory from lect./books	3.67	-2.14	0.58

Appendix 13 *x*, *Z* and *s.d.* of specific learning objectives for UE: practical coordinators

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
17	F	Present essentials of an exp. in written form	1.13	1.75	0.35
9	E	Interpret reliability and meaning of results	1.25	1.5	0.46
25	F	Communicate exp. findings in written form	1.25	1.5	0.46
62	D	Conduct experiments safely	1.25	1.5	0.46
84	A	Understand the purpose of an experiment	1.25	1.5	0.46
87	E	Analyze exp. data to draw conclusions	1.25	1.5	0.46
91	A	Understand what is to be measured in an exp.	1.37	1.24	0.74
4	D	Use practical (as opposed to theoretical) lab skills	1.38	1.22	0.52
61	D	Observe phenomena in a quantitative way	1.38	1.22	0.52
77	C	Properly plan an experiment	1.38	1.22	0.52
80	D	Collect experimental data	1.38	1.22	0.74
28	D	Carry out accurate measurements	1.5	0.97	0.53
47	E	Evaluate exp. outcome with respect to a hypothesis	1.5	0.97	0.53
102	E	Evaluate diff. expected & actual results	1.5	0.97	0.53
16	E	Assess relevance of exp. data with regard to hypothesis	1.5	0.97	0.76
71	F	Describe central aspects of an experiment	1.63	0.7	0.52
34	E	Apply elementary notions of statistics	1.63	0.7	0.74
52	E	Process experimental data	1.63	0.7	0.74
64	C	Recogn. hazards so as to take safety precautions	1.63	0.7	0.74
98	A	Understand measurement of diff. phenomena	1.63	0.7	0.92
31	C	Design an exp. to verify a theory/hypothesis	1.75	0.45	0.46
12	D	Put basic lab. techniques to use	1.75	0.45	0.71
75	B	Apply known principles to new situations	1.75	0.45	0.71
85	D	Handle modern equipment	1.75	0.45	0.71
56	E	Evaluate contribution direct to derived errors	1./5	0.45	1.04
94	8	React adequately to unforeseen results	1.87	0.2	0.64
18	D	Manipulate apparati	1.88	0.18	0.83
1	E	Make order-of-magnitude calculations and estimates	2	-0.07	0.53
19	E	Apply principles instead of rote formulae	2	-0.07	0.53
21	A	Decompose large to smaller problems	2	-0.07	0.53
22	C	Design subsequent exp. involving phenomena	2	-0.07	0.53
86	C	Understand scope & limits of exp. techniques used	2	-0.07	0.53
23	A	Derive testable hypotheses from theories	2	-0.07	0.76
72	F	Suggest follow-up investigations	2	-0.07	0.76
89	D	Set up lab equipment quickly & correctly	2	-0.07	0.76
97	E	Relate exp. outcomes to a particular theory	2	-0.07	0.76
33	A	Use exp. data to solve specific problems	2	-0.07	0.82
55	F	Summarize an exp. based on results	2	-0.07	1
35	B	Apply current knowledge in solving new problems	2	-0.07	1.31
26	E	Use obtained data to make estimates in new situations	2.13	-0.34	0.35
10	E	Estimate outcome of exp. meas. within given precision	2.13	-0.34	0.64
42	F	Communicate exp. findings in oral form	2.13	-0.34	0.64
53	D	Keep a day-to-day lab diary	2.13	-0.34	0.83
54	A	Derive & evaluate relationships	2.13	-0.34	0.83
44	D	Be flexible in modifying exp.	2.13	-0.34	1.36
68	D	Handle waste safely	2.13	-0.34	1.36
5	D	Observe phenomena in a qualitative way	2.25	-0.6	0.46
92	D	Know & apply altern. meas. techniques	2.25	-0.6	0.46
95	C	Design relevant observation techniques	2.25	-0.6	0.71
88	C	Translate conc. def. into set of meas. procedures	2.25	-0.6	0.89
45	B	Construct models based on exp. findings	2.25	-0.6	1.04
38	B	Construct models which fit exp. evidence	2.38	-0.87	0.92
83	F	Discuss results with other scientists	2.38	-0.87	0.92
63	A	Solve problems in a multi-solution situation	2.38	-0.87	1.19
101	D	Understand lab instructions	2.38	-0.87	1.19
41	B	Recognize & define scientific problems	2.5	-1.12	1.31
46	A	Identify variables & determine emp. relations	2.63	-1.39	1.3
29	A	Solve difficult scientific problems	2.63	-1.39	1.77
43	E	Incorporate unexpected exp. results in new model	2.75	-1.64	0.71
20	D	Calibrate instruments	2.75	-1.64	0.89
32	C	Develop measurement techniques	2.75	-1.64	1.16
24	D	Follow instructions	2.88	-1.91	1.25
100	E	Confirm facts, princ. & theory from lect./books	3	-2.16	1.15
65	E	Confirm already known facts and laws	3.29	-2.77	0.95

Appendix 14 *x*, *Z* and *s.d.* of specific learning objectives for UE: non-practical coordinators

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	x	Z	s.d.
62	D	Conduct experiments safely	1.36	1.47	0.5
84	A	Understand the purpose of an experiment	1.36	1.47	0.5
91	A	Understand what is to be measured in an exp.	1.36	1.47	0.5
9	E	Interpret reliability and meaning of results	1.43	1.33	0.51
64	C	Recogn. hazards so as to take safety precautions	1.43	1.33	0.85
17	F	Present essentials of an exp. in written form	1.5	1.19	0.52
25	F	Communicate exp. findings in written form	1.5	1.19	0.52
101	D	Understand lab instructions	1.5	1.19	0.52
16	E	Assess relevance of exp. data with regard to hypothesis	1.5	1.19	0.65
56	E	Evaluate contribution direct to derived errors	1.54	1.12	0.52
77	C	Properly plan an experiment	1.57	1.06	0.51
47	E	Evaluate exp. outcome with respect to a hypothesis	1.64	0.92	0.5
55	F	Summarize an exp. based on results	1.64	0.92	0.5
28	D	Carry out accurate measurements	1.64	0.92	0.63
1	E	Make order-of-magnitude calculations and estimates	1.64	0.92	0.63
68	D	Handle waste safely	1.64	0.92	0.84
87	E	Analyze exp. data to draw conclusions	1.71	0.79	0.47
61	D	Observe phenomena in a quantitative way	1.79	0.63	0.43
52	E	Process experimental data	1.79	0.63	0.43
98	A	Understand measurement of diff. phenomena	1.79	0.63	0.43
80	D	Collect experimental data	1.79	0.63	0.58
102	E	Evaluate diff. expected & actual results	1.79	0.63	0.58
71	F	Describe central aspects of an experiment	1.79	0.63	0.58
4	D	Use practical (as opposed to theoretical) lab skills	1.79	0.63	0.7
34	E	Apply elementary notions of statistics	1.79	0.63	0.8
5	D	Observe phenomena in a qualitative way	1.86	0.49	0.66
86	C	Understand scope & limits of exp. techniques used	1.93	0.36	0.62
10	E	Estimate outcome of exp. meas. within given precision	1.93	0.36	0.62
33	A	Use exp. data to solve specific problems	1.93	0.36	0.73
97	E	Relate exp. outcomes to a particular theory	2	0.22	0.39
19	E	Apply principles instead of rote formulae	2	0.22	0.68
35	B	Apply current knowledge in solving new problems	2.07	0.09	0.73
31	C	Design an exp. to verify a theory/hypothesis	2.07	0.09	1
12	D	Put basic lab. techniques to use	2.07	0.09	1.07
21	A	Decompose large to smaller problems	2.14	-0.05	0.86
22	C	Design subsequent exp. involving phenomena	2.14	-0.05	0.86
26	E	Use obtained data to make estimates in new situations	2.14	-0.05	0.95
42	F	Communicate exp. findings in oral form	2.14	-0.05	1.1
72	F	Suggest follow-up investigations	2.21	-0.19	0.8
75	B	Apply known principles to new situations	2.29	-0.34	0.73
24	D	Follow instructions	2.36	-0.48	0.93
41	B	Recognize & define scientific problems	2.36	-0.48	1.08
23	A	Derive testable hypotheses from theories	2.36	-0.48	1.15
53	D	Keep a day-to-day lab diary	2.36	-0.48	1.39
89	D	Set up lab equipment quickly & correctly	2.43	-0.61	0.65
94	B	React adequately to unforeseen results	2.43	-0.61	0.94
44	D	Be flexible in modifying exp.	2.43	-0.61	0.94
38	B	Construct models which fit exp. evidence	2.43	-0.61	1.16
46	A	Identify variables & determine emp. relations	2.5	-0.75	0.76
85	D	Handle modern equipment	2.5	-0.75	0.85
45	B	Construct models based on exp. findings	2.5	-0.75	0.94
18	D	Manipulate apparati	2.5	-0.75	1.02
20	D	Calibrate instruments	2.57	-0.89	1.16
88	C	Translate conc. def. into set of meas. procedures	2.64	-1.02	0.74
92	D	Know & apply altern. meas. techniques	2.64	-1.02	0.93
54	A	Derive & evaluate relationships	2.69	-1.12	0.63
63	A	Solve problems in a multi-solution situation	2.71	-1.16	0.99
43	E	Incorporate unexpected exp. results in new model	2.85	-1.43	1.28
83	F	Discuss results with other scientists	2.86	-1.45	1.23
95	C	Design relevant observation techniques	2.93	-1.58	1.07
32	C	Develop measurement techniques	3.14	-1.99	0.86
29	A	Solve difficult scientific problems	3.21	-2.13	1.12
65	E	Confirm already known facts and laws	3.36	-2.42	0.93
100	E	Confirm facts, princ. & theory from lect./books	3.36	-2.42	1.08

Appendix 15 $\bar{x}$, Z and *s.d.* of specific end-terms for UE institutes

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
79	I	Have a critical attitude to exp. results	1.45	2.09	0.51
3	II	Solve problems in a critical, academic way	1.64	1.67	0.58
69	II	Do experiments	1.73	1.47	1.08
14	I	Make decisions in proper course of action of prob-solving	1.86	1.18	0.71
15	I	Form attitudes related to value & uses of exp. science	1.86	1.18	0.89
37	I	Discover limitations of a theory/model	1.91	1.07	0.68
6	II	Deeply understand the discipline studied	1.91	1.07	0.75
8	II	Approach observed phenomena from a scient. point of view	1.95	0.98	0.72
2	II	Use the lab as an instrument for discovery	2	0.87	0.76
48	I	Plan ahead	2.05	0.76	0.72
49	I	Formulate a problem that can be researched	2.09	0.67	1.23
74	I	Interpret data in literature	2.14	0.56	0.71
66	I	Approach a problem with an open mind	2.14	0.56	1.08
27	II	Be interested in the subject area	2.18	0.47	1.1
90	I	Survey literature relevant to some problem	2.18	0.47	1.18
39	I	Act independently & take initiative	2.27	0.27	0.55
57	I	Apply one's insights, discoveries & conclusions	2.27	0.27	0.7
76	II	Design new exp. in their own fields	2.36	0.07	0.85
78	II	Experience spirit & essence of scient. inquiry	2.36	0.07	0.95
30	II	Determine limits under which a theory applies	2.36	0.07	1.14
99	I	Use mental skills inherent to professionals	2.45	-0.13	1.06
11	I	Work in groups to solve scient. problems	2.45	-0.13	1.18
81	II	Appreciate relationship between nature & science	2.5	-0.24	1.06
13	II	Illustrate facts, princ. & theory of lectures/books	2.52	-0.29	1.03
96	II	Work in research & development labs	2.55	-0.35	1.3
50	II	Experience challenge of exp. method	2.59	-0.44	1.05
40	I	Concretize theoretical notions	2.62	-0.51	0.8
67	I	Take active part in the process of science	2.64	-0.55	1.09
60	II	Experience past and present scientists' joy	2.73	-0.75	1.24
7	I	Use motor skills inherent to professionals	2.81	-0.93	1.08
70	I	Work independently of others	2.86	-1.04	0.94
51	I	Appreciate the usual & unusual	2.91	-1.16	1.19
73	II	Experience joys & sorrows of experimenting	2.91	-1.16	1.44
82	I	Tackle a problem without help of others	3.05	-1.47	0.95
36	II	Intuitively understand scientific phenomena	3.05	-1.47	1.18
58	I	Be self-confident and independent	3.14	-1.67	1.17
93	II	Experience kinship with the scientist	3.18	-1.76	1.1
59	II	Build framework for facts, princ & theory from lect/books	3.19	-1.78	1.08

Appendix 16 $\bar{x}$, Z and *s.d.* of specific end-terms for HVE institutes

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
69	II	Do experiments	1.36	2.21	0.74
79	I	Have a critical attitude to exp. results	1.43	2.05	0.51
48	I	Plan ahead	1.71	1.45	0.61
90	I	Survey literature relevant to some problem	1.79	1.28	0.89
27	II	Be interested in the subject area	1.79	1.28	0.97
3	II	Solve problems in a critical, academic way	1.86	1.13	0.53
14	I	Make decisions in proper course of action of prob-solving	1.93	0.97	0.62
66	I	Approach a problem with an open mind	1.93	0.97	0.73
15	I	Form attitudes related to value & uses of exp. science	2	0.82	0.68
74	I	Interpret data in literature	2	0.82	0.78
57	I	Apply one's insights, discoveries & conclusions	2.07	0.67	0.73
58	I	Be self-confident and independent	2.14	0.52	0.53
7	I	Use motor skills inherent to professionals	2.14	0.52	0.77
39	I	Act independently & take initiative	2.14	0.52	0.77
6	II	Deeply understand the discipline studied	2.21	0.37	0.7
2	II	Use the lab as an instrument for discovery	2.21	0.37	1.05
96	II	Work in research & development labs	2.21	0.37	1.37
11	I	Work in groups to solve scient. problems	2.29	0.2	0.91
13	II	Illustrate facts, princ. & theory of lectures/books	2.36	0.05	0.63
70	I	Work independently of others	2.43	-0.1	1.45
8	II	Approach observed phenomena from a scient. point of view	2.57	-0.41	0.65
78	II	Experience spirit & essence of scient. inquiry	2.57	-0.41	0.65
81	II	Appreciate relationship between nature & science	2.64	-0.56	0.63
40	I	Concretize theoretical notions	2.64	-0.56	0.84
99	I	Use mental skills inherent to professionals	2.64	-0.56	0.93
67	I	Take active part in the process of science	2.64	-0.56	1.08
50	II	Experience challenge of exp. method	2.71	-0.71	0.83
93	II	Experience kinship with the scientist	2.79	-0.88	0.97
30	II	Determine limits under which a theory applies	2.79	-0.88	1.05
73	II	Experience joys & sorrows of experimenting	2.79	-0.88	1.05
51	I	Appreciate the usual & unusual	2.86	-1.03	0.86
76	II	Design new exp. in their own fields	2.86	-1.03	1.1
49	I	Formulate a problem that can be researched	2.93	-1.18	1
59	II	Build framework for facts, princ & theory from lect/books	3	-1.34	0.78
60	II	Experience past and present scientists' joy	3	-1.34	0.78
36	II	Intuitively understand scientific phenomena	3	-1.34	1
82	I	Tackle a problem without help of others	3	-1.34	1.04
37	I	Discover limitations of a theory/model	3.07	-1.49	1.07

Appendix 17 *x*, *Z* and *s.d.* of specific end-terms for UE-biology

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
49	I	Formulate a problem that can be researched	1.2	1.48	0.45
3	II	Solve problems in a critical, academic way	1.4	1.13	0.55
14	I	Make decisions in proper course of action of prob-solving	1.4	1.13	0.55
66	I	Approach a problem with an open mind	1.4	1.13	0.55
2	II	Use the lab as an instrument for discovery	1.6	0.78	0.55
6	II	Deeply understand the discipline studied	1.6	0.78	0.55
8	II	Approach observed phenomena from a scient. point of view	1.6	0.78	0.55
27	II	Be interested in the subject area	1.6	0.78	0.55
78	II	Experience spirit & essence of scient. inquiry	1.6	0.78	0.55
79	I	Have a critical attitude to exp. results	1.6	0.78	0.55
15	I	Form attitudes related to value & uses of exp. science	1.6	0.78	0.89
67	I	Take active part in the process of science	1.6	0.78	0.89
69	II	Do experiments	1.6	0.78	0.89
30	II	Determine limits under which a theory applies	1.8	0.43	0.45
37	I	Discover limitations of a theory/model	1.8	0.43	0.45
60	II	Experience past and present scientists' joy	1.8	0.43	0.45
76	II	Design new exp. in their own fields	1.8	0.43	0.45
81	II	Appreciate relationship between nature & science	1.8	0.43	0.45
73	II	Experience joys & sorrows of experimenting	1.8	0.43	0.84
57	I	Apply one's insights, discoveries & conclusions	2	0.08	0
40	I	Concretize theoretical notions	2	0.08	0.71
50	II	Experience challenge of exp. method	2	0.08	0.71
51	I	Appreciate the usual & unusual	2	0.08	0.71
74	I	Interpret data in literature	2	0.08	0.71
90	I	Survey literature relevant to some problem	2	0.08	0.71
99	I	Use mental skills inherent to professionals	2	0.08	0.71
39	I	Act independently & take initiative	2.2	-0.27	0.45
96	II	Work in research & development labs	2.2	-0.27	1.64
11	I	Work in groups to solve scient. problems	2.4	-0.62	1.14
13	II	Illustrate facts, princ. & theory of lectures/books	2.4	-0.62	1.14
48	I	Plan ahead	2.4	-0.62	1.14
59	II	Build framework for facts, princ & theory from lect/books	2.8	-1.32	0.84
70	I	Work independently of others	2.8	-1.32	0.84
82	I	Tackle a problem without help of others	2.8	-1.32	0.84
93	II	Experience kinship with the scientist	3	-1.67	1.22
7	I	Use motor skills inherent to professionals	3.2	-2.02	1.3
58	I	Be self-confident and independent	3.4	-2.37	1.14
36	II	Intuitively understand scientific phenomena	3.5	-2.54	0.58

Appendix 18 x, *Z* and *s.d.* of specific end-terms for UE-chemistry

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
79	I	Have a critical attitude to exp. results	1.25	2.06	0.46
69	II	Do experiments	1.25	2.06	0.71
3	II	Solve problems in a critical, academic way	1.38	1.83	0.52
6	II	Deeply understand the discipline studied	1.5	1.61	0.76
2	II	Use the lab as an instrument for discovery	1.63	1.38	0.52
15	I	Form attitudes related to value & uses of exp. science	1.75	1.17	1.04
48	I	Plan ahead	1.88	0.94	0.64
37	I	Discover limitations of a theory/model	1.88	0.94	0.83
14	I	Make decisions in proper course of action of prob-solving	1.88	0.94	0.99
74	I	Interpret data in literature	2	0.72	0.53
8	II	Approach observed phenomena from a scient. point of view	2	0.72	0.93
90	I	Survey literature relevant to some problem	2.13	0.49	1.55
27	II	Be interested in the subject area	2.25	0.27	1.28
39	I	Act independently & take initiative	2.38	0.04	0.74
13	II	Illustrate facts, princ. & theory of lectures/books	2.38	0.04	1.19
66	I	Approach a problem with an open mind	2.38	0.04	1.3
78	II	Experience spirit & essence of scient. inquiry	2.38	0.04	1.3
11	I	Work in groups to solve scient. problems	2.38	0.04	1.41
49	I	Formulate a problem that can be researched	2.38	0.04	1.41
57	I	Apply one's insights, discoveries & conclusions	2.5	-0.17	0.76
76	II	Design new exp. in their own fields	2.5	-0.17	1.07
96	II	Work in research & development labs	2.5	-0.17	1.69
7	I	Use motor skills inherent to professionals	2.63	-0.4	0.92
30	II	Determine limits under which a theory applies	2.63	-0.4	1.3
40	I	Concretize theoretical notions	2.75	-0.62	0.89
70	I	Work independently of others	2.75	-0.62	1.04
50	II	Experience challenge of exp. method	2.75	-0.62	1.39
99	II	Use mental skills inherent to professionals	2.75	-0.62	1.58
67	I	Take active part in the process of science	2.88	-0.85	1.13
36	II	Intuitively understand scientific phenomena	2.88	-0.85	1.46
81	II	Appreciate relationship between nature & science	2.88	-0.85	1.46
51	I	Appreciate the usual & unusual	3	-1.07	1.31
58	I	Be self-confident and independent	3	-1.07	1.31
60	II	Experience past and present scientists' joy	3	-1.07	1.6
73	II	Experience joys & sorrows of experimenting	3	-1.07	1.69
59	II	Build framework for facts, princ & theory from lect/books	3.25	-1.51	1.28
82	I	Tackle a problem without help of others	3.25	-1.51	1.28
93	II	Experience kinship with the scientist	3.38	-1.74	1.51

Appendix 19 $\bar{x}$, Z and $s.d.$ of specific end-terms for UE-physics

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	x	Z	s.d.
79	I	Have a critical attitude to exp. results	1.33	2.9	0.52
14	I	Make decisions in proper course of action of prob-solving	2	1.41	0
8	II	Approach observed phenomena from a scient. point of view	2	1.41	0.63
69	II	Do experiments	2	1.41	1.55
3	II	Solve problems in a critical, academic way	2.17	1.03	0.41
37	I	Discover limitations of a theory/model	2.17	1.03	0.41
39	I	Act independently & take initiative	2.17	1.03	0.41
48	I	Plan ahead	2.17	1.03	0.41
15	I	Form attitudes related to value & uses of exp. science	2.17	1.03	0.75
57	I	Apply one's insights, discoveries & conclusions	2.33	0.67	1.03
6	II	Deeply understand the discipline studied	2.5	0.3	0.55
99	I	Use mental skills inherent to professionals	2.5	0.3	0.55
50	II	Experience challenge of exp. method	2.5	0.3	0.84
76	II	Design new exp. in their own fields	2.5	0.3	0.84
81	II	Appreciate relationship between nature & science	2.5	0.3	0.84
74	I	Interpret data in literature	2.5	0.3	1.05
40	I	Concretize theoretical notions	2.6	0.07	0.55
78	II	Experience spirit & essence of scient. inquiry	2.67	-0.08	0.52
96	II	Work in research & development labs	2.67	-0.08	0.82
66	I	Approach a problem with an open mind	2.67	-0.08	1.03
90	I	Survey literature relevant to some problem	2.67	-0.08	1.21
27	II	Be interested in the subject area	2.67	-0.08	1.37
36	II	Intuitively understand scientific phenomena	2.8	-0.37	1.3
2	II	Use the lab as an instrument for discovery	2.83	-0.44	0.75
82	I	Tackle a problem without help of others	2.83	-0.44	0.75
30	II	Determine limits under which a theory applies	2.83	-0.44	1.17
49	I	Formulate a problem that can be researched	2.83	-0.44	1.17
60	II	Experience past and present scientists' joy	2.83	-0.44	1.17
70	I	Work independently of others	2.83	-0.44	1.17
58	I	Be self-confident and independent	3	-0.82	1.1
67	I	Take active part in the process of science	3	-0.82	1.1
7	I	Use motor skills inherent to professionals	3	-0.82	1.41
11	I	Work in groups to solve scient. problems	3.17	-1.2	0.75
93	II	Experience kinship with the scientist	3.17	-1.2	0.75
13	II	Illustrate facts, princ. & theory of lectures/books	3.2	-1.26	0.84
51	I	Appreciate the usual & unusual	3.33	-1.55	1.37
73	II	Experience joys & sorrows of experimenting	3.33	-1.55	1.51
59	II	Build framework for facts, princ & theory from lect/books	3.6	-2.16	1.14

Appendix 20 Order of magnitude of differences in normalized learning objective scores between HVE and UE

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	HVE	UE	ΔZ
20	D	Calibrate instruments	0.59	-1.21	1.8
100	E	Confirm facts, princ. & theory from lect./books	-0.7	-2.46	1.76
65	E	Confirm already known facts and laws	-0.92	-2.65	1.73
31	C	Design an exp. to verify a theory/hypothesis	-1.28	0.23	1.51
41	B	Recognize & define scientific problems	-2.21	-0.73	1.48
23	A	Derive testable hypotheses from theories	-1.74	-0.36	1.38
24	D	Follow instructions	0.34	-1.02	1.36
45	B	Construct models based on exp. findings	-2.09	-0.73	1.36
83	F	Discuss results with other scientists	0	-1.29	1.29
18	D	Manipulate apparati	0.81	-0.44	1.25
38	B	Construct models which fit exp. evidence	-1.98	-0.73	1.25
53	D	Keep a day-to-day lab diary	0.7	-0.44	1.14
47	E	Evaluate exp. outcome with respect to a hypothesis	0	0.98	0.98
16	E	Assess relevance of exp. data with regard to hypothesis	0.23	1.17	0.94
12	D	Put basic lab. techniques to use	1.16	0.23	0.93
22	C	Design subsequent exp. involving phenomena	-0.92	-0.06	0.86
5	D	Observe phenomena in a qualitative way	0.81	0.12	0.69
101	D	Understand lab instructions	1.16	0.5	0.66
63	A	Solve problems in a multi-solution situation	-0.47	-1.11	0.64
42	F	Communicate exp. findings in oral form	-0.46	-0.17	0.63
84	A	Understand the purpose of an experiment	0.93	1.54	0.61
29	A	Solve difficult scientific problems	-2.55	-1.96	0.59
86	C	Understand scope & limits of exp. techniques used	0.81	0.23	0.58
80	D	Collect experimental data	1.4	0.87	0.53
61	D	Observe phenomena in a quantitative way	0.34	0.87	0.53
26	E	Use obtained data to make estimates in new situations	0.34	-0.17	0.51
46	A	Identify variables & determine emp. relations	-1.51	-1.02	0.49
85	D	Handle modern equipment	0.12	-0.36	0.48
94	B	React adequately to unforeseen results	0.12	-0.36	0.48
87	E	Analyze exp. data to draw conclusions	0.59	1.06	0.47
19	E	Apply principles instead of rote formulae	-0.35	0.12	0.47
97	E	Relate exp. outcomes to a particular theory	-0.35	0.12	0.47
98	A	Understand measurement of diff. phenomena	0.23	0.69	0.46
92	D	Know & apply altern. meas. techniques	-0.47	-0.92	0.45
25	F	Communicate exp. findings in written form	0.93	1.35	0.42
54	A	Derive & evaluate relationships	-1.28	-0.88	0.4
62	D	Conduct experiments safely	1.16	1.54	0.38
88	C	Translate conc. def. into set of meas. procedures	-1.28	-0.92	0.36
77	C	Properly plan an experiment	0.81	1.17	0.36
102	E	Evaluate diff. expected & actual results	0.46	0.79	0.33
44	D	Be flexible in modifying exp.	-0.22	-0.54	0.32
9	E	Interpret reliability and meaning of results	1.16	1.46	0.3
43	E	Incorporate unexpected exp. results in new model	-1.85	-1.56	0.29
75	B	Apply known principles to new situations	-0.35	-0.06	0.29
34	E	Apply elementary notions of statistics	0.93	0.69	0.24
64	C	Recogn. hazards so as to take safety precautions	0.93	1.17	0.24
52	E	Process experimental data	0.46	0.69	0.23
71	F	Describe central aspects of an experiment	0.46	0.69	0.23
33	A	Use exp. data to solve specific problems	0	0.23	0.23
89	D	Set up lab equipment quickly & correctly	-0.22	-0.44	0.22
32	C	Develop measurement techniques	-1.74	-1.96	0.22
56	E	Evaluate contribution direct to derived errors	0.7	0.92	0.22
91	A	Understand what is to be measured in an exp.	1.27	1.46	0.19
21	A	Decompose large to smaller problems	0.12	-0.06	0.18
4	D	Use practical (as opposed to theoretical) lab skills	0.7	0.87	0.17
1	E	Make order-of-magnitude calculations and estimates	0.7	0.6	0.1
35	B	Apply current knowledge in solving new problems	0.12	0.02	0.1
68	D	Handle waste safely	0.59	0.5	0.09
55	F	Summarize an exp. based on results	0.7	0.62	0.08
28	D	Carry out accurate measurements	1.04	0.98	0.06
72	F	Suggest follow-up investigations	-0.11	-0.17	0.06
17	F	Present essentials of an exp. in written form	1.4	1.46	0.06
95	C	Design relevant observation techniques	-1.28	-1.29	0.01
10	E	Estimate outcome of exp. meas. within given precision	0.12	0.12	0

n.b.: ΔZ is an absolute score

Appendix 21 Order of magnitude of differences in normalized learning objective scores between OuN and HVE

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	OuN	HVE	ΔZ
27	D	Calibrate instruments	-2.95	0.59	3.54
23	A	Derive testable hypotheses from theories	0.98	-1.74	2.72
18	D	Manipulate apparati	-1.9	0.81	2.71
41	B	Recognize & define scientific problems	0.46	-2.21	2.67
43	E	Incorporate unexpected exp. results in new model	0.58	-1.85	2.43
12	D	Put basic lab. techniques to use	-1.24	1.16	2.4
45	B	Construct models based on exp. findings	0.19	-2.09	2.28
80	D	Collect experimental data	-0.85	1.4	2.25
85	D	Handle modern equipment	-2.02	0.12	2.14
29	A	Solve difficult scientific problems	-0.59	-2.55	1.96
89	D	Set up lab equipment quickly & correctly	-2.17	-0.22	1.95
38	B	Construct models which fit exp. evidence	-0.06	-1.98	1.92
54	A	Derive & evaluate relationships	0.58	-1.28	1.86
28	D	Carry out accurate measurements	-0.72	1.04	1.76
31	C	Design an exp. to verify a theory/hypothesis	0.46	-1.28	1.74
24	D	Follow instructions	-1.38	0.34	1.72
4	D	Use practical (as opposed to theoretical) lab skills	-0.99	0.7	1.69
101	D	Understand lab instructions	-0.45	1.16	1.61
22	C	Design subsequent exp. involving phenomena	0.58	-0.92	1.5
97	E	Relate exp. outcomes to a particular theory	0.98	-0.35	1.33
62	D	Conduct experiments safely	0.07	1.16	1.09
75	B	Apply known principles to new situations	0.73	-0.35	1.08
92	D	Know & apply altern. meas. techniques	-1.51	-0.47	1.04
16	E	Assess relevance of exp. data with regard to hypothesis	1.24	0.23	1.01
95	C	Design relevant observation techniques	-0.33	-1.28	0.95
32	C	Develop measurement techniques	-2.69	-1.74	0.95
63	A	Solve problems in a multi-solution situation	0.46	-0.47	0.93
46	A	Identify variables & determine emp. relations	-0.59	-1.51	0.92
21	A	Decompose large to smaller problems	0.98	0.12	0.86
65	E	Confirm already known facts and laws	-1.77	-0.92	0.85
44	D	Be flexible in modifying exp.	0.58	-0.22	0.8
52	E	Process experimental data	-0.33	0.46	0.79
53	D	Keep a day-to-day lab diary	-0.06	0.7	0.76
47	E	Evaluate exp. outcome with respect to a hypothesis	0.73	0	0.73
17	F	Present essentials of an exp. in written form	0.73	1.4	0.67
94	B	React adequately to unforeseen results	0.73	0.12	0.61
71	F	Describe central aspects of an experiment	0.98	0.46	0.52
102	E	Evaluate diff. expected & actual results	0.98	0.46	0.52
86	C	Understand scope & limits of exp. techniques used	0.33	0.81	0.48
9	E	Interpret reliability and meaning of results	1.64	1.16	0.48
33	A	Use exp. data to solve specific problems	0.46	0	0.46
98	A	Understand measurement of diff. phenomena	-0.2	0.23	0.43
100	E	Confirm facts, princ. & theory from lect./books	-1.11	-0.7	0.41
68	D	Handle waste safely	0.19	0.59	0.4
55	F	Summarize an exp. based on results	0.33	0.7	0.37
56	E	Evaluate contribution direct to derived errors	0.33	0.7	0.37
25	F	Communicate exp. findings in written form	0.58	0.93	0.35
77	C	Properly plan an experiment	0.46	0.81	0.35
10	E	Estimate outcome of exp. meas. within given precision	0.46	0.12	0.34
35	B	Apply current knowledge in solving new problems	0.46	0.12	0.34
34	E	Apply elementary notions of statistics	1.24	0.93	0.31
19	E	Apply principles instead of rote formulae	-0.06	-0.35	0.29
91	A	Understand what is to be measured in an exp.	0.98	1.27	0.29
64	C	Recogn. hazards so as to take safety precautions	0.73	0.93	0.2
83	F	Discuss results with other scientists	-0.2	0	0.2
72	F	Suggest follow-up investigations	0.07	-0.11	0.18
61	D	Observe phenomena in a quantitative way	0.19	0.34	0.15
1	E	Make order-of-magnitude calculations and estimates	0.85	0.7	0.15
87	E	Analyze exp. data to draw conclusions	0.73	0.59	0.14
42	F	Communicate exp. findings in oral form	0.33	0.46	0.13
26	E	Use obtained data to make estimates in new situations	0.46	0.34	0.12
5	D	Observe phenomena in a qualitative way	0.73	0.81	0.08
84	A	Understand the purpose of an experiment	0.85	0.93	0.08
88	C	Translate conc. def. into set of meas. procedures	-1.24	-1.28	0.04

n.b.: ΔZ is an absolute score

Appendix 22 Order of magnitude of differences in normalized learning objective scores between OuN and UE

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	OuN	UE	ΔZ
43	E	Incorporate unexpected exp. results in new model	0.58	-1.56	2.14
4	D	Use practical (as opposed to theoretical) lab skills	-0.99	0.87	1.86
20	D	Calibrate instruments	-2.95	-1.21	1.74
89	D	Set up lab equipment quickly & correctly	-2.17	-0.44	1.73
80	D	Collect experimental data	-0.85	0.87	1.72
28	D	Carry out accurate measurements	-0.72	0.98	1.7
85	D	Handle modern equipment	-2.02	-0.36	1.66
63	A	Solve problems in a multi-solution situation	0.46	-1.11	1.57
12	D	Put basic lab. techniques to use	-1.24	0.23	1.47
62	D	Conduct experiments safely	0.07	1.54	1.47
18	D	Manipulate apparati	-1.9	-0.44	1.46
54	A	Derive & evaluate relationships	0.58	-0.88	1.46
29	A	Solve difficult scientific problems	-0.59	-1.96	1.37
100	E	Confirm facts, princ. & theory from lect./books	-1.11	-2.46	1.35
23	A	Derive testable hypotheses from theories	0.98	-0.36	1.34
41	B	Recognize & define scientific problems	0.46	-0.73	1.19
44	D	Be flexible in modifying exp.	0.58	-0.54	1.12
83	F	Discuss results with other scientists	-0.2	-1.29	1.09
94	B	React adequately to unforeseen results	0.73	-0.36	1.09
21	A	Decompose large to smaller problems	0.98	-0.06	1.04
52	E	Process experimental data	-0.33	0.69	1.02
95	C	Design relevant observation techniques	-0.33	-1.29	0.96
101	D	Understand lab instructions	-0.45	0.5	0.95
45	B	Construct models based on exp. findings	0.19	-0.73	0.92
98	A	Understand measurement of diff. phenomena	-0.2	0.69	0.89
65	E	Confirm already known facts and laws	-1.77	-2.65	0.88
97	E	Relate exp. outcomes to a particular theory	0.98	0.12	0.86
75	B	Apply known principles to new situations	0.73	-0.06	0.79
25	F	Communicate exp. findings in written form	0.58	1.35	0.77
17	F	Present essentials of an exp. in written form	0.73	1.46	0.73
32	C	Develop measurement techniques	-2.69	-1.96	0.73
77	C	Properly plan an experiment	0.46	1.17	0.71
84	A	Understand the purpose of an experiment	0.85	1.54	0.69
61	D	Observe phenomena in a quantitative way	0.19	0.87	0.68
38	B	Construct models which fit exp. evidence	-0.06	-0.73	0.67
22	C	Design subsequent exp. involving phenomena	0.58	-0.06	0.64
26	E	Use obtained data to make estimates in new situations	0.46	-0.17	0.63
5	D	Observe phenomena in a qualitative way	0.73	0.12	0.61
56	E	Evaluate contribution direct to derived errors	0.33	0.92	0.59
92	D	Know & apply altern. meas. techniques	-1.51	-0.92	0.59
34	E	Apply elementary notions of statistics	1.24	0.69	0.55
42	F	Communicate exp. findings in oral form	0.33	-0.17	0.5
91	A	Understand what is to be measured in an exp.	0.98	1.46	0.48
35	B	Apply current knowledge in solving new problems	0.46	0.02	0.44
64	C	Recogn. hazards so as to take safety precautions	0.73	1.17	0.44
46	A	Identify variables & determine emp. relations	-0.59	-1.02	0.43
53	D	Keep a day-to-day lab diary	-0.06	-0.44	0.38
24	D	Follow instructions	-1.38	-1.02	0.36
10	E	Estimate outcome of exp. meas. within given precision	0.46	0.12	0.34
87	E	Analyze exp. data to draw conclusions	0.73	1.06	0.33
88	C	Translate conc. def. into set of meas. procedures	-1.24	-0.92	0.32
68	D	Handle waste safely	0.19	0.5	0.31
55	F	Summarize an exp. based on results	0.33	0.62	0.29
71	F	Describe central aspects of an experiment	0.98	0.69	0.29
1	E	Make order-of-magnitude calculations and estimates	0.85	0.6	0.25
47	E	Evaluate exp. outcome with respect to a hypothesis	0.73	0.98	0.25
72	F	Suggest follow-up investigations	0.07	-0.17	0.24
31	C	Design an exp. to verify a theory/hypothesis	0.46	0.23	0.23
33	A	Use exp. data to solve specific problems	0.46	0.23	0.23
102	E	Evaluate diff. expected & actual results	0.98	0.79	0.19
9	E	Interpret reliability and meaning of results	1.64	1.46	0.18
19	E	Apply principles instead of rote formulae	-0.06	0.12	0.18
86	C	Understand scope & limits of exp. techniques used	0.33	0.23	0.1
16	E	Assess relevance of exp. data with regard to hypothesis	1.24	1.17	0.07

n.b.: ΔZ is an absolute score

Appendix 23 Order of magnitude of differences in normalized learning objective scores between OuN and UE-biology

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	OuN	UE biol.	ΔZ
12	D	Put basic lab. techniques to use	-1.24	1.01	2.25
20	D	Calibrate instruments	-2.95	-0.71	2.24
100	E	Confirm facts, princ. & theory from lect./books	-1.11	-2.87	1.76
28	D	Carry out accurate measurements	-0.72	1.01	1.73
4	D	Use practical (as opposed to theoretical) lab skills	-0.99	0.58	1.57
5	D	Observe phenomena in a qualitative way	0.73	-0.71	1.44
94	B	React adequately to unforeseen results	0.73	-0.71	1.44
80	D	Collect experimental data	-0.85	0.58	1.43
54	A	Derive & evaluate relationships	0.58	-0.82	1.4
26	E	Use obtained data to make estimates in new situations	0.46	-0.71	1.17
63	A	Solve problems in a multi-solution situation	0.46	-0.71	1.17
34	E	Apply elementary notions of statistics	1.24	0.15	1.09
89	D	Set up lab equipment quickly & correctly	-2.17	-1.15	1.02
46	A	Identify variables & determine emp. relations	-0.59	-1.58	0.99
77	C	Properly plan an experiment	0.46	1.45	0.99
88	C	Translate conc. def. into set of meas. procedures	-1.24	-0.28	0.96
83	F	Discuss results with other scientists	-0.2	-1.15	0.95
62	D	Conduct experiments safely	0.07	1.01	0.94
91	A	Understand what is to be measured in an exp.	0.98	1.88	0.9
43	E	Incorporate unexpected exp. results in new model	0.58	-0.28	0.86
21	A	Decompose large to smaller problems	0.98	0.15	0.83
97	E	Relate exp. outcomes to a particular theory	0.98	0.15	0.83
68	D	Handle waste safely	0.19	1.01	0.82
92	D	Know & apply altern. meas. techniques	-1.51	-0.71	0.8
98	A	Understand measurement of diff. phenomena	-0.2	0.58	0.78
41	B	Recognize & define scientific problems	0.46	-0.28	0.74
1	E	Make order-of-magnitude calculations and estimates	0.85	0.15	0.7
55	F	Summarize an exp. based on results	0.33	1.01	0.68
65	E	Confirm already known facts and laws	-1.77	-2.44	0.67
19	E	Apply principles instead of rote formulae	-0.06	0.58	0.64
38	B	Construct models which fit exp. evidence	-0.06	0.58	0.64
16	E	Assess relevance of exp. data with regard to hypothesis	1.24	1.88	0.64
9	E	Interpret reliability and meaning of results	1.64	1.01	0.63
86	C	Understand scope & limits of exp. techniques used	0.33	-0.28	0.61
101	D	Understand lab instructions	-0.45	0.15	0.6
75	B	Apply known principles to new situations	0.73	0.15	0.58
87	E	Analyze exp. data to draw conclusions	0.73	0.15	0.58
29	A	Solve difficult scientific problems	-0.59	-1.15	0.56
31	C	Design an exp. to verify a theory/hypothesis	0.46	1.01	0.55
72	F	Suggest follow-up investigations	0.07	0.58	0.51
52	E	Process experimental data	-0.33	0.15	0.48
22	C	Design subsequent exp. involving phenomena	0.58	0.15	0.43
44	D	Be flexible in modifying exp.	0.58	0.15	0.43
23	A	Derive testable hypotheses from theories	0.98	0.58	0.4
71	F	Describe central aspects of an experiment	0.98	0.58	0.4
102	E	Evaluate diff. expected & actual results	0.98	0.58	0.4
61	D	Observe phenomena in a quantitative way	0.19	0.58	0.39
95	C	Design relevant observation techniques	-0.33	-0.71	0.38
18	D	Manipulate apparati	-1.9	-1.58	0.32
10	E	Estimate outcome of exp. meas. within given precision	0.46	0.15	0.31
33	A	Use exp. data to solve specific problems	0.46	0.15	0.31
35	B	Apply current knowledge in solving new problems	0.46	0.15	0.31
47	E	Evaluate exp. outcome with respect to a hypothesis	0.73	1.01	0.28
32	C	Develop measurement techniques	-2.69	-2.44	0.25
42	F	Communicate exp. findings in oral form	0.33	0.58	0.25
56	E	Evaluate contribution direct to derived errors	0.33	0.58	0.25
53	D	Keep a day-to-day lab diary	-0.06	-0.28	0.22
24	D	Follow instructions	-1.38	-1.58	0.2
84	A	Understand the purpose of an experiment	0.85	1.01	0.16
17	F	Present essentials of an exp. in written form	0.73	0.58	0.15
64	C	Recogn. hazards so as to take safety precautions	0.73	0.58	0.15
45	B	Construct models based on exp. findings	0.19	0.15	0.04
85	D	Handle modern equipment	-2.03	-2.01	0.02
25	F	Communicate exp. findings in written form	0.58	0.58	0

n.b.: ΔZ is an absolute score

Appendix 24 Order of magnitude of differences in normalized learning objective scores between OuN and UE-chemistry

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	OuN	UE chem.	ΔZ
43	E	Incorporate unexpected exp. results in new model	0.58	-1.98	2.56
85	D	Handle modern equipment	-2.03	0.25	2.28
80	D	Collect experimental data	-0.85	1.22	2.07
18	D	Manipulate apparati	-1.9	-0.01	1.89
12	D	Put basic lab. techniques to use	-1.24	0.49	1.73
41	B	Recognize & define scientific problems	0.46	-1.25	1.71
89	D	Set up lab equipment quickly & correctly	-2.17	-0.5	1.67
62	D	Conduct experiments safely	0.07	1.71	1.64
83	F	Discuss results with other scientists	-0.2	-1.74	1.54
4	D	Use practical (as opposed to theoretical) lab skills	-0.99	0.49	1.48
23	A	Derive testable hypotheses from theories	0.98	-0.5	1.48
20	D	Calibrate instruments	-2.95	-1.49	1.46
28	D	Carry out accurate measurements	-0.72	0.72	1.44
101	D	Understand lab instructions	-0.45	0.98	1.43
95	C	Design relevant observation techniques	-0.33	-1.74	1.41
54	A	Derive & evaluate relationships	0.58	-0.76	1.34
21	A	Decompose large to smaller problems	0.98	-0.26	1.24
32	C	Develop measurement techniques	-2.69	-1.49	1.2
45	B	Construct models based on exp. findings	0.19	-0.99	1.18
22	C	Design subsequent exp. involving phenomena	0.58	-0.5	1.08
44	D	Be flexible in modifying exp.	0.58	-0.5	1.08
52	E	Process experimental data	-0.33	0.72	1.05
77	C	Properly plan an experiment	0.46	1.47	1.01
75	B	Apply known principles to new situations	0.73	-0.26	0.99
94	B	React adequately to unforeseen results	0.73	-0.26	0.99
97	E	Relate exp. outcomes to a particular theory	0.98	-0.01	0.99
65	E	Confirm already known facts and laws	-1.77	-2.73	0.96
29	A	Solve difficult scientific problems	-0.59	-1.49	0.9
24	D	Follow instructions	-1.38	-0.5	0.88
100	E	Confirm facts, princ. & theory from lect./books	-1.11	-1.98	0.87
42	F	Communicate exp. findings in oral form	-0.5	0.33	0.83
72	F	Suggest follow-up investigations	0.07	-0.76	0.83
61	D	Observe phenomena in a quantitative way	0.19	0.98	0.79
68	D	Handle waste safely	0.19	0.98	0.79
71	F	Describe central aspects of an experiment	0.98	0.23	0.75
92	D	Know & apply altern. meas. techniques	-1.51	-0.76	0.75
87	E	Analyze exp. data to draw conclusions	0.73	1.47	0.74
10	E	Estimate outcome of exp. meas. within given precision	0.46	-0.26	0.72
38	B	Construct models which fit exp. evidence	-0.06	-0.76	0.7
98	A	Understand measurement of diff. phenomena	-0.2	0.49	0.69
25	F	Communicate exp. findings in written form	0.58	1.22	0.64
84	A	Understand the purpose of an experiment	0.85	1.47	0.62
16	E	Assess relevance of exp. data with regard to hypothesis	1.24	0.72	0.52
33	A	Use exp. data to solve specific problems	0.46	0.98	0.52
34	E	Apply elementary notions of statistics	1.24	0.72	0.52
5	D	Observe phenomena in a qualitative way	0.73	0.23	0.5
17	F	Present essentials of an exp. in written form	0.73	1.22	0.49
64	C	Recogn. hazards so as to take safety precautions	0.73	1.22	0.49
26	E	Use obtained data to make estimates in new situations	0.46	-0.01	0.47
31	C	Design an exp. to verify a theory/hypothesis	0.46	-0.01	0.47
35	B	Apply current knowledge in solving new problems	0.46	-0.01	0.47
9	E	Interpret reliability and meaning of results	1.64	1.22	0.42
1	E	Make order-of-magnitude calculations and estimates	0.85	0.49	0.36
102	E	Evaluate diff. expected & actual results	0.98	0.72	0.26
47	E	Evaluate exp. outcome with respect to a hypothesis	0.73	0.98	0.25
91	A	Understand what is to be measured in an exp.	0.98	1.22	0.24
63	A	Solve problems in a multi-solution situation	0.46	0.23	0.23
53	D	Keep a day-to-day lab diary	-0.06	-0.26	0.2
56	E	Evaluate contribution direct to derived errors	0.33	0.49	0.16
86	C	Understand scope & limits of exp. techniques used	0.33	0.49	0.16
46	A	Identify variables & determine emp. relations	-0.59	-0.5	0.09
55	F	Summarize an exp. based on results	0.33	0.25	0.08
19	E	Apply principles instead of rote formulae	-0.06	-0.01	0.05
88	C	Translate conc. def. into set of meas. procedures	-1.24	-1.25	0.01

n.b.: ΔZ is an absolute score

Appendix 25 Order of magnitude of differences in normalized learning objective scores between OuN and UE-physics

The first column gives the item number for the specific learning objective from the inventory (appendix 4). The letters in the second column correspond with the general learning objectives.

		Objective	OuN	UE phys.	ΔZ
85	D	Handle modern equipment	-2.03	0.67	2.7
63	A	Solve problems in a multi-solution situation	0.46	-2.14	2.6
18	D	Manipulate apparati	-1.9	0.67	2.57
89	D	Set up lab equipment quickly & correctly	-2.17	0.38	2.55
4	D	Use practical (as opposed to theoretical) lab skills	-0.99	1.23	2.22
20	D	Calibrate instruments	-2.95	-0.74	2.21
43	E	Incorporate unexpected exp. results in new model	0.58	-1.59	2.17
28	D	Carry out accurate measurements	-0.72	1.23	1.95
29	A	Solve difficult scientific problems	-0.59	-2.43	1.84
80	D	Collect experimental data	-0.85	0.94	1.79
23	A	Derive testable hypotheses from theories	0.98	-0.74	1.72
44	D	Be flexible in modifying exp.	0.58	-1.01	1.59
68	D	Handle waste safely	0.19	-1.3	1.49
41	B	Recognize & define scientific problems	0.46	-1.01	1.47
32	C	Develop measurement techniques	-2.69	-1.3	1.39
12	D	Put basic lab. techniques to use	-1.24	0.1	1.34
52	E	Process experimental data	-0.33	0.94	1.27
62	D	Conduct experiments safely	0.07	1.23	1.16
21	A	Decompose large to smaller problems	0.98	-0.17	1.15
42	F	Communicate exp. findings in oral form	0.33	-0.74	1.07
92	D	Know & apply altern. meas. techniques	-1.51	-0.46	1.05
54	A	Derive & evaluate relationships	0.58	-0.46	1.04
38	B	Construct models which fit exp. evidence	-0.06	-1.01	0.95
45	B	Construct models based on exp. findings	0.19	-0.74	0.93
35	B	Apply current knowledge in solving new problems	0.46	-0.46	0.92
56	E	Evaluate contribution direct to derived errors	0.33	1.23	0.9
75	B	Apply known principles to new situations	0.73	-0.17	0.9
98	A	Understand measurement of diff. phenomena	-0.2	0.67	0.87
100	E	Confirm facts, princ. & theory from lect./books	-1.11	-1.97	0.86
83	F	Discuss results with other scientists	-0.2	-1.01	0.81
17	F	Present essentials of an exp. in written form	0.73	1.51	0.78
22	C	Design subsequent exp. involving phenomena	0.58	-0.17	0.75
33	A	Use exp. data to solve specific problems	0.46	-0.29	0.75
61	D	Observe phenomena in a quantitative way	0.19	0.94	0.75
84	A	Understand the purpose of an experiment	0.85	1.51	0.66
25	F	Communicate exp. findings in written form	0.58	1.23	0.65
26	E	Use obtained data to make estimates in new situations	0.46	-0.17	0.63
31	C	Design an exp. to verify a theory/hypothesis	0.46	-0.17	0.63
97	E	Relate exp. outcomes to a particular theory	0.98	0.38	0.6
65	E	Confirm already known facts and laws	-1.77	-2.31	0.54
88	C	Translate conc. def. into set of meas. procedures	-1.24	-0.74	0.5
46	A	Identify variables & determine emp. relations	-0.59	-1.01	0.42
95	C	Design relevant observation techniques	-0.33	-0.74	0.41
10	E	Estimate outcome of exp. meas. within given precision	0.46	0.1	0.36
5	D	Observe phenomena in a qualitative way	0.73	0.38	0.35
94	B	React adequately to unforeseen results	0.73	0.38	0.35
16	E	Assess relevance of exp. data with regard to hypothesis	1.24	0.94	0.3
34	E	Apply elementary notions of statistics	1.24	0.94	0.3
101	D	Understand lab instructions	-0.45	-0.17	0.2B
91	A	Understand what is to be measured in an exp.	0.98	1.23	0.25
86	C	Understand scope & limits of exp. techniques used	0.33	0.1	0.23
77	C	Properly plan an experiment	0.46	0.67	0.21
64	C	Recogn. hazards so as to take safety precautions	0.73	0.94	0.21
B7	E	Analyze exp. data to draw conclusions	0.73	0.94	0.21
1	E	Make order-of-magnitude calculations and estimates	0.85	0.67	0.18
19	E	Apply principles instead of rote formulae	-0.06	0.1	0.16
9	E	Interpret reliability and meaning of results	1.64	1.51	0.13
53	D	Keep a day-to-day lab diary	-0.06	-0.17	0.11
24	D	Follow instructions	-1.38	-1.3	0.08
47	E	Evaluate exp. outcome with respect to a hypothesis	0.73	0.67	0.06
55	F	Summarize an exp. based on results	0.33	0.38	0.05
71	F	Describe central aspects of an experiment	0.98	0.94	0.04
102	E	Evaluate diff. expected & actual results	0.98	0.94	0.04
72	F	Suggest follow-up investigations	0.07	0.1	0.03

n.b.: ΔZ is an absolute score

Appendix 26 Order of magnitude of differences in normalized end-term scores between HVE and UE

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	HVE	UE	AZ
37	I	Discover limitations of a theory/model	-1.49	1.07	2.56
58	I	Be self-confident and independent	0.52	-1.67	2.19
49	I	Formulate a problem that can be researched	-1.18	0.67	1.85
7	I	Use motor skills inherent to professionals	0.52	-0.93	1.45
8	II	Approach observed phenomena from a scient. point of view	-0.41	0.98	1.39
76	II	Design new exp. in their own fields	-1.03	0.07	1.1
30	II	Determine limits under which a theory applies	-0.88	0.07	0.95
70	I	Work independently of others	-0.1	-1.04	0.94
93	II	Experience kinship with the scientist	-0.88	-1.76	0.88
27	II	Be interested in the subject area	1.28	0.47	0.81
90	I	Survey literature relevant to some problem	1.28	0.47	0.81
69	II	Do experiments	2.21	1.47	0.74
96	II	Work in research & development labs	0.37	-0.35	0.72
6	II	Deeply understand the discipline studied	0.37	1.07	0.7
48	I	Plan ahead	1.45	0.76	0.69
60	II	Experience past and present scientists' joy	-1.34	-0.75	0.59
3	II	Solve problems in a critical, academic way	1.13	1.67	0.54
2	II	Use the lab as an instrument for discovery	0.37	0.87	0.5
78	II	Experience spirit & essence of scient. inquiry	-0.41	0.07	0.48
59	II	Build framework for facts, princ & theory from lect/books	-1.34	-1.78	0.44
99	I	Use mental skills inherent to professionals	-0.56	-0.13	0.43
66	I	Approach a problem with an open mind	0.97	0.56	0.41
57	I	Apply one's insights, discoveries & conclusions	0.67	0.27	0.4
15	I	Form attitudes related to value & uses of exp. science	0.82	1.18	0.36
13	II	Illustrate facts, princ. & theory of lectures/books	0.05	-0.29	0.34
11	I	Work in groups to solve scient. problems	0.2	-0.13	0.33
81	II	Appreciate relationship between nature & science	-0.56	-0.24	0.32
73	II	Experience joys & sorrows of experimenting	-0.88	-1.16	0.28
50	II	Experience challenge of exp. method	-0.71	-0.44	0.27
74	I	Interpret data in literature	0.82	0.56	0.26
39	I	Act independently & take initiative	0.52	0.27	0.25
14	I	Make decisions in proper course of action of prob-solving	0.97	1.18	0.21
51	I	Appreciate the usual & unusual	-1.03	-1.16	0.13
36	II	Intuitively understand scientific phenomena	-1.34	-1.47	0.13
82	I	Tackle a problem without help of others	-1.34	-1.47	0.13
40	I	Concretize theoretical notions	-0.56	-0.51	0.05
79	I	Have a critical attitude to exp. results	2.05	2.09	0.04
67	I	Take active part in the process of science	-0.56	-0.55	0.01

n.b.: AZ is an absolute score

Appendix 27 Order of magnitude of differences in normalized end-term scores between OuN and HVE

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	OuN	HVE	ΔZ
69	II	Do experiments	-0.72	2.21	2.93
8	II	Approach observed phenomena from a scient. point of view	1.88	-0.41	2.29
96	II	Work in research & development labs	-1.88	0.37	2.25
37	I	Discover limitations of a theory/model	0.72	-1.49	2.21
49	I	Formulate a problem that can be researched	1.01	-1.18	2.19
7	I	Use motor skills inherent to professionals	-1.59	0.52	2.11
48	I	Plan ahead	0.15	1.45	1.3
27	II	Be interested in the subject area	0.15	1.28	1.13
59	II	Build framework for facts, princ & theory from lect/books	-0.29	-1.34	1.05
3	II	Solve problems in a critical, academic way	2.16	1.13	1.03
76	II	Design new exp. in their own fields	-0.01	[illegible]	1.02
2	II	Use the lab as an instrument for discovery	-0.44	[illegible]	0.81
13	II	Illustrate facts, princ. & theory of lectures/books	-0.72	0.05	0.77
73	II	Experience joys & sorrows of experimenting	-1.59	-0.88	0.71
58	I	Be self-confident and independent	-0.15	0.52	0.67
14	I	Make decisions in proper course of action of prob-solving	1.59	0.97	0.62
51	I	Appreciate the usual & unusual	-0.44	-1.03	0.59
93	II	Experience kinship with the scientist	-1.45	-0.88	0.57
50	II	Experience challenge of exp. method	-0.15	-0.71	0.56
81	II	Appreciate relationship between nature & science	-0.01	-0.56	0.55
36	II	Intuitively understand scientific phenomena	-0.88	-1.34	0.46
82	I	Tackle a problem without help of others	-0.88	-1.34	0.46
79	I	Have a critical attitude to exp. results	1.59	2.05	0.46
30	II	Determine limits under which a theory applies	-0.44	-0.88	0.44
67	I	Take active part in the process of science	-0.15	-0.56	0.41
57	I	Apply one's insights, discoveries & conclusions	0.28	0.67	0.39
6	II	Deeply understand the discipline studied	0.72	0.37	0.35
74	I	Interpret data in literature	1.15	0.82	0.33
90	I	Survey literature relevant to some problem	1.59	1.28	0.31
11	I	Work in groups to solve scient. problems	-0.01	0.2	0.21
70	I	Work independently of others	-0.29	-0.1	0.19
99	I	Use mental skills inherent to professionals	-0.72	-0.56	0.16
78	II	Experience spirit & essence of scient. inquiry	-0.29	-0.41	0.12
66	I	Approach a problem with an open mind	0.86	0.97	0.11
60	II	Experience past and present scientists' joy	-1.45	-1.34	0.11
15	I	Form attitudes related to value & uses of exp. science	0.72	0.82	0.1
39	I	Act independently & take initiative	0.58	0.52	0.06
40	I	Concretize theoretical notions	-0.58	-0.56	0.02

n.b.: ΔZ is an absolute score

Appendix 28 Order of magnitude of differences in normalized end-term scores between OuN and UE

The first column gives the item number for the specific end-term from the inventory (appendix 4). The roman numerals in column two correspond with the general end-terms.

		End-term	OuN	UE	ΔZ
69	II	Do experiments	-0.72	1.47	2.19
96	II	Work in research & development labs	-1.88	-0.35	1.53
58	I	Be self-confident and independent	-0.15	-1.67	1.52
59	II	Build framework for facts, princ & theory from lect/books	-0.29	-1.78	1.49
2	II	Use the lab as an instrument for discovery	-0.44	0.87	1.31
90	I	Survey literature relevant to some problem	1.59	0.47	1.12
8	II	Approach observed phenomena from a scient. point of view	1.88	0.98	0.9
70	I	Work independently of others	-0.29	-1.04	0.75
51	I	Appreciate the usual & unusual	-0.44	-1.16	0.72
60	II	Experience past and present scientists' joy	-1.45	-0.75	0.7
7	I	Use motor skills inherent to professionals	-1.59	-0.93	0.66
48	I	Plan ahead	0.15	0.76	0.61
74	I	Interpret data in literature	1.15	0.56	0.59
36	II	Intuitively understand scientific phenomena	-0.88	-1.47	0.59
82	I	Tackle a problem without help of others	-0.88	-1.47	0.59
99	I	Use mental skills inherent to professionals	-0.72	-0.13	0.59
30	II	Determine limits under which a theory applies	-0.44	0.07	0.51
79	I	Have a critical attitude to exp. results	1.59	2.09	0.5
3	II	Solve problems in a critical, academic way	2.16	1.67	0.49
15	I	Form attitudes related to value & uses of exp. science	0.72	1.18	0.46
13	II	Illustrate facts, princ. & theory of lectures/books	-0.72	-0.29	0.43
73	II	Experience joys & sorrows of experimenting	-1.59	-1.16	0.43
14	I	Make decisions in proper course of action of prob-solving	1.59	1.18	0.41
67	I	Take active part in the process of science	-0.15	-0.55	0.4
78	II	Experience spirit & essence of scient. inquiry	-0.29	0.07	0.36
6	II	Deeply understand the discipline studied	0.72	1.07	0.35
37	I	Discover limitations of a theory/model	0.72	1.07	0.35
49	I	Formulate a problem that can be researched	1.01	0.67	0.34
27	II	Be interested in the subject area	0.15	0.47	0.32
39	I	Act independently & take initiative	0.58	0.27	0.31
93	II	Experience kinship with the scientist	-1.45	-1.76	0.31
66	I	Approach a problem with an open mind	0.86	0.56	0.3
50	II	Experience challenge of exp. method	-0.15	-0.44	0.29
81	II	Appreciate relationship between nature & science	-0.01	-0.24	0.23
11	I	Work in groups to solve scient. problems	-0.01	-0.13	0.12
76	II	Design new exp. in their own fields	-0.01	0.07	0.08
40	I	Concretize theoretical notions	-0.58	-0.51	0.07
57	I	Apply one's insights, discoveries & conclusions	0.28	0.27	0.01

n.b.: ΔZ is an absolute score

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